COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Four Sided Seal Tester

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Results and Accomplishments (November 2006 – June 2009)

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14. ABSTRACT

Four Sided Seal Testing is an alternative method that can be used to test the seal strength of Combat Ration Pouches. This method allows the food to remain in the pouch while the seals are being tested and all four seals of the pouch are tested at the same time. This method is quicker and uses less pouches and thus results into cost savings.
This project studied the interaction of the plate gap and the burst strength of a pouch. By using this relationship, a revised internal pressure specification for MRE's that allows a wider confinement plate gap than 0.5" was developed.
In addition, minimum required seal strength of the Institutional Sized Retort Pouch was determined that assures the pouch to survive the typical shipping abuse tests.

15. SUBJECT TERMS

MRE, ISP, Internal Pressure Test, Four Side Seal Test, Rations, Seal Strength

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Abstract:

Four Sided Seal Testing is an alternative method that can be used to test the seal strength of Combat Ration Pouches. This method allows the food to remain in the pouch while all four seals of the pouch are tested at the same time. The four sided seal test method is quicker and uses less pouches than the standard three sided seal tester, and thus results into cost savings. However, MIL-PRF-44073F required that the gap of the confinement plates, between which the pouch is tested, is set at a 0.5" gap for MRE pouches and a 2" gap for Institutional pouches. Both size pouches needed to be inflated to 20 psig for 30 seconds and show no significant seal creep. Most 8 oz MRE pouches are thicker than 0.5" and could not be tested using the four sided seal tester. Most Institutional pouches failed the 20 psig test with a 2" gap.

This project established the interaction between the plate gap and the burst strength of a pouch. By using this relationship, we developed and validated a revised internal pressure specification for MRE's that allows a wider confinement plate gap than 0.5". Based on this work, the internal pressure condition listed in MIL-PRF-44073 were changed and now allows the use of a 1" plate gap for MRE pouches with a reduced internal pressure test requirements of 12 psig for 30 seconds.

To determine the appropriate internal pressure conditions for the ISP, pouches with a wide variety of seal strength were produced. By exposing these pouches to drop and vibration tests, the minimum required seal strength of the pouch was determined that assured the pouch to survive these abusive conditions. Recommendations were then made to reduce the inflation pressure for these pouches from 20 psig to 10 psig, while the pouch is constraint between two plates with a 2" gap.

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1 Results and Accomplishments

1.1 Introduction and Background

Current specifications for pouches (MIL-PRF-44073F) require that the seal strength of pouches is tested by means of an internal pressure test. The seals need to withstand a minimum internal pressure of 20 psig for 30 sec, while the pouch is constraint between two plates that are 0.5" apart. Two test methods are allowed, the most common method is the three sided seal tester and an alternate method is a four sided seal tester.

The original seal test method for MRE pouches is a three-seal tester that pressurizes the pouch through an open end. Prior to the test, the content of the pouch needs to be removed. In this test the top closure seal is cut off. The empty pouch is confined between two plates that are ½" apart. The pouch is then inflated with 20 psig air for 30 seconds. To test the closure seal, the bottom seal shall be cut off and the same test is repeated. Therefore this test requires that two pouches are used to test all four seals.

The four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) tests all four seals simultaneously. The advantage of the four seal tester is that only one pouch needs to be used to test all four seals and that the content of the pouch does not have to be removed prior to the test. This makes the four sided seal tester more cost effective and faster than the three-seal tester.

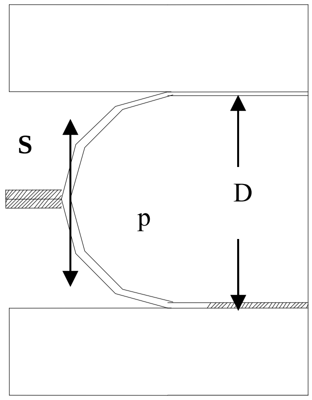
However, the test protocol for the four sided seal tester requires that the plates distance is set at ½" for MRE pouches, while a 8 oz filled retorted pouch thickness typically range from 5/8" to 7/8" and pre-retorted pouches might even be 1" thick. Therefore, the four sided seal test methodology, as currently listed in the Military Specification can not be used for most MRE pouches.

Increasing the gap of the confinement plates is being proposed. However, this will increase the forces that are created on the seal by the internal pressure of the pouch. It is estimated that doubling the gap from ½" to 1" gap could double the force on the seal. Therefore, to test the seal for a certain minimal strength, the internal pressure would need to be reduced accordingly.

The test methodology for Institutional Sized Pouch specifies a plate distance of 2", while maintaining the internal pressure at 20 psig for 30 seconds. Industry members that have tested ISP at these conditions have remarked that pouches consistently fail at these test conditions, even though these pouches seem to survive the drop and vibration tests. Therefore, it is hypothesized that a less stringent internal pressure can be used to assure a minimal seal strength and survivability of the pouch in a normal military distribution system.

Several researches have proposed models for the correlation of seal peel strength and the burst pressure of flexible packages. While there is some disagreement on the best suited model, all researches agree that the peel force on the seal increases with the gap distance of the restraining plates.

Dr Yam published a theoretical model for correlation of peel and burst test for pouches (Packaging Technology and Science 6 (1993): 239-244



S = p . R (S=Seal Peel Force, p=internal pressure, R= Radius film)
Dr Yam's model is based on the circular shape of the pouch near the seal

Yam's model was evaluated by Feliu-Baez. The results showed that Yam's model over estimated the burst pressure. Several alternate theoretical models were developed, but none yielded better results than Dr Yam's model. Only empirical models yielded better results. All models demonstrated that increasing the gap of the plates would increase the force on the seal under the same internal pressure conditions.

1.2 Objectives

1.2.1 Objective #1

Develop and validate an empirical model for Military pouches that established a relationship between the internal pressure, distance of the confinement plates and the forces on the seal by correlating the internal pressure required to burst the pouch as function of the plate distance to the forces required to separate the seal in a peel test.

1.2.2 Objective #2

Develop and validate an internal pressure test condition that assures that an Institutional Pouch will survive normal distribution abuse in the military distribution system.

1.3 Results and Conclusions

Based on the empirical relationships that were established between internal pressure, the gap of the confinement plates and the forces on the seal, equivalent test conditions were recommended that allows the use of confinement plate gap in excess of 0.5". This data was then used to revise the packaging specification for retortable MRE pouches and allow the producers to use a four sided seal tester with a 1" gap and a 12 psig internal pressure test condition for 30 seconds.

The project also evaluated the internal pressure test conditions for Institutional sized pouches and recommended that reduced internal pressure conditions (10 psig for 30 seconds with a 2" plate gap) could be used while still assuring that these pouches would survive the vibration and drop test conditions used by the Natick Army lab.

2 Program Management

The project was awarded on November 9, 2006, under SPO103-02-D-0024, delivery order 0015, with a partial obligation ($100,000) of the total requested amount of $149,163. Performance period for this delivery order was initially set at 12 months from November 9, 2006 through November 8, 2007. The final deliverable of the project was: “Internal pressure test specification for four sided seal tester as function of confinement plate distance”

The following modifications were issued:

- Jul 18, 2007 0013/01 Obligation of the remaining budget ($49,163) increasing the total funds obligated to $149,163
- Nov 7, 2007 0012/02 No cost extension of the performance period through to November 8, 2008
- Nov 7, 2008 0012/03 No cost extension of the performance period through June 30, 2009

3 Short Term Project Activities

3.1 Phase I: “Method Development”

3.1.1 Literature Search

Several references were found in the literature that correlate the burst pressure to the peel strength of a pouch. The most basic model is given by Dr Yam who predicts that the peel force (F_y) on the seal is equivalent half of the internal pressure (p) times the plate distance (D): $F_y = p.D/2$

From equilibrium of an element of 1 inch thickness at an angle θ,

$$dF_y = (p.R.d\theta)\sin\theta$$
$$dF_x = (p.R.d\theta)\cos\theta$$
$$F_y = \int_{\theta=0}^{\theta=\pi/2} (p.R.d\theta)\sin\theta$$
$$= pR\int_{\theta=0}^{\theta=\pi/2} \sin\theta d\theta = pD/2$$

The film peeling force per unit length

$$F_p = \frac{pD}{2} = \left(\frac{ph}{2}\right) \qquad lb/inch$$

The film hoop stress σ_θ is given by:

$$\sigma_\theta = \frac{pD}{2t} \quad psi$$

$$Hence, \sigma_x = \sigma_y = \left(\frac{pD}{2t}\right) = \left(\frac{ph}{2t}\right) - - - - - (1)$$

where "h" is the platten seperation gap

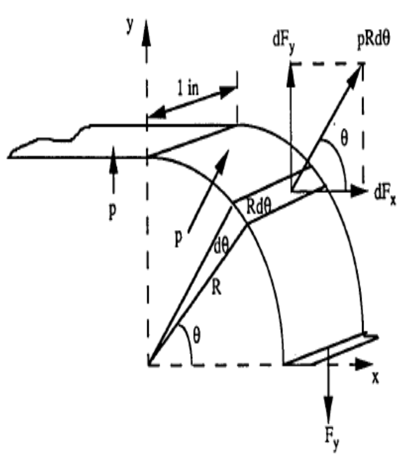


Figure 2:. Force Analysis on Straight Part

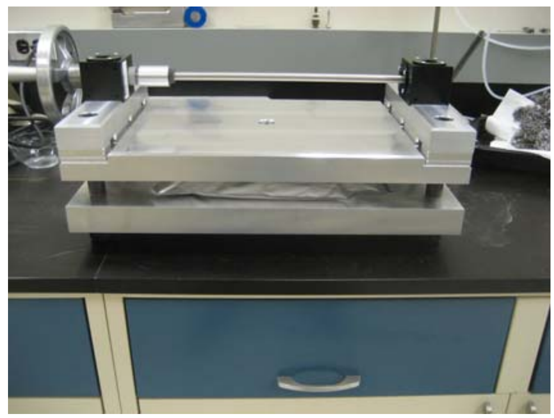
Feliu'-Baez et al. indicated that Yam's model over estimated the burst pressure by 22-49%. An attempt to develop a more refined theoretical model was not successful and the development of an empirical model required a larger set of tests to be performed for a single application. They developed a model for a Tyvek pouch (peelable seals). Because the MRE seals are fusion seals, the model developed by Feliu-Baez at al was not applicable for this project.

3.1.2 Methodology Development

In order to develop a correlation model between burst pressure and peel strength of pouches, a wide variety of pouch materials from different vendors and sealed under different conditions were used. ASTM standards for burst testing (ASTM F2054) and peel testing (ASTM F88) were used.

Burst Testing

An in-house tester four sided seal tester was developed that could easily be adjusted from a ½" gap to a 2" gap at ¼" increments and be able to test MRE's and ISP's. The protocol for the burst test (ASTM F2054) was slightly adjusted:



a) Each pouch was inflated until burst occurred, using four different plate distances. Plate distance for MRE were ½", ¾", 1" and 1-1/4", and for ISP: ½" 1", 1.5" and 2"
b) Pouch were initially inflated to a starting pressure and held for 30 seconds. The pressure was then increased 5 psig (ramp ~ 1 psig/sec) and held for 30 seconds. This 5 psig pressure increase was repeated until burst occurred. The pressure at which the pouch burst occurred was recorded. If the failure occurred during the ramp, the last hold pressure plus 2.5 psig was recorded
c) The test was replicated at least five times for each pouch/plate condition.

Peel Strength Testing

A Chatillon TCD200 tensile tester was used for the seal peel test. The following protocol was used:

a) Samples of each pouch material were taken, 1" wide, 2 samples per seal side, for a total of 8 samples/pouch. The sample locations was marked so that seal strength data could be evaluated based on location..
b) Each sample was tested for seal strength following ASTM F88 protocol, using 12 inch/min separation speed. The peak force, the elongation at peak, the energy to reach peak force and the total energy to separate were recorded
c) The test was replicated for each pouch at least five times.
d) The minimum peel strength of each pouch was determined and later used in the correlation study with burst pressure, as the minimal seal strength, represents the weakest link

3.2 *Phase II: "Lab Testing MRE"*

3.2.1 Analytical Analysis

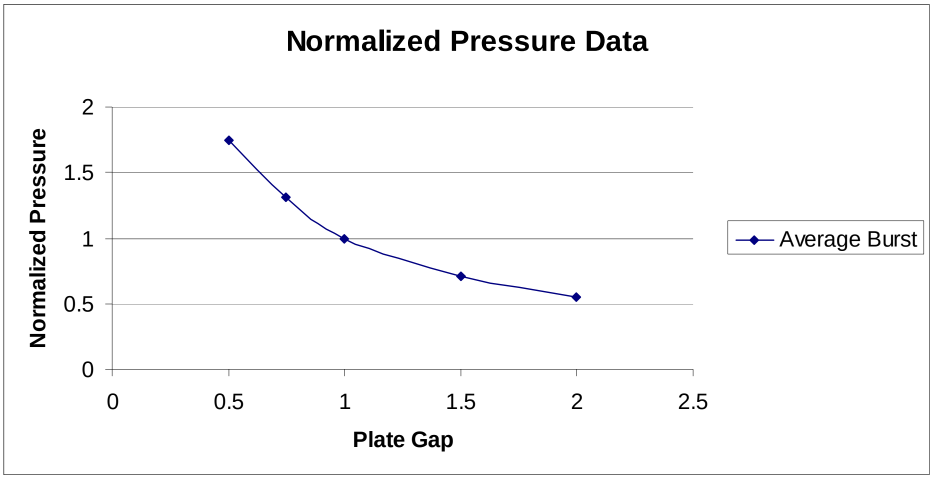
3.2.2 Sealing Studies MRE Pouches

A total of twelve different pouch populations were tested for seal strength and burst pressure, following the above protocols. Six pouch populations were retorted MRE's pouches, two populations were retorted ISP's and four populations were Bakery pouches:

- Horizontal Form Fill Seal, 8 oz MRE sourced from Ameriqual
- Horizontal Form Fill Seal, 5 oz MRE sourced from Ameriqual
- Horizontal Form Fill Seal, 8 oz MRE sourced from the CORANET Demo Site
- Preformed MRE, 8 oz, sourced via Ameriqual, sealed by Demo Site
- Preformed MRE, 5 oz, sourced via Ameriqual, sealed by Demo Site
- Preformed MRE, 8 oz, sourced by Demo Site and sealed by Demo Site
- HFFS Bakery Pouch, Hoaah Bar, sourced from Sterling
- HFFS Bakery Pouch, Fig Bar, sourced from Sterling
- HFFS Bakery Pouch, Sports Bar, sourced from Sterling
- HFFS Bakery Pouch, Snack Bread, sourced from Sterling
- Institutional Pouch, sourced from Demo Site, sealed by Demo Site
- Institutional Pouch, sourced from Natick, sealed by Demo Site

3.2.3 Data Analysis of Pouch Seal Strength

Detailed data from the burst test and peel test and subsequent analysis is reported in Technical working Paper (TWP)#223. A summary graph of this data is displayed below. The chart depicts the normalized relationship of the burst pressure of a pouch versus the plate gap, using the plate gap of 1" as the norm. As the plate gap increases, the burst pressure decreases as expected.



Based on a 20 psig internal pressure requirement for plate distances of 0.5" (current mil spec for retort pouches), the following pressure settings for plate distances that are greater then 0.5" should yield similar accept/reject rates, assuming that more than 60% of the pouch remains in contact with the confinement plates:

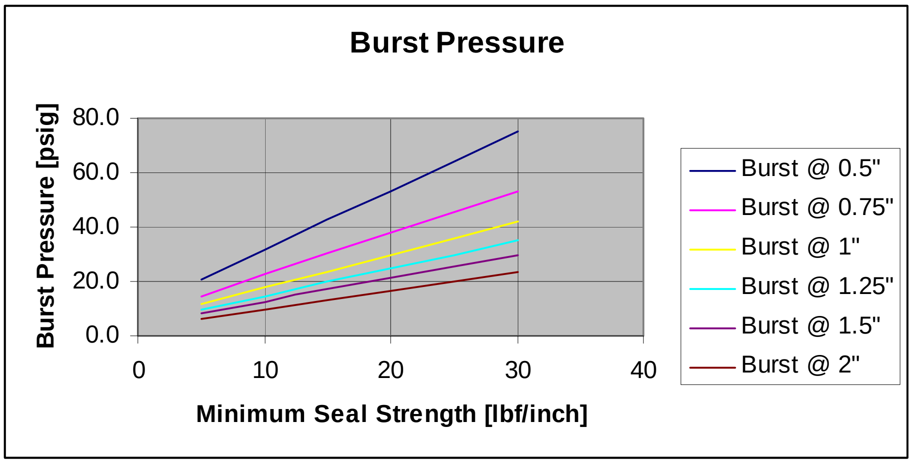
0.5"	20 psig for 30 sec
0.75"	15 psig for 30 sec
1.00"	12 psig for 30 sec
1.25"	10 psig for 30 sec

1.50” 8 psig for 30 sec
2.00” 7 psig for 30 sec

Based on a 14 psig pressure requirement for plate distances of 0.5” (current mil spec for bakery pouches), the following pressure settings for plate distances that are greater then 0.5” should yield similar accept/reject rates, assuming that more than 60% of the pouch remains in contact with the confinement plates:

0.5” 14 psig for 30 sec
0.75” 10 psig for 30 sec
1.00” 8 psig for 30 sec
1.25” 7 psig for 30 sec
1.50” 6 psig for 30 sec
2.00” 5 psig for 30 sec

The graph below shows the correlation between the minimum seal strength of a pouch seal and the burst pressure as function of the plate gap used.



3.3 Phase III: “Implementation”

Based on the empirical models, recommendations were made to the Army R&D Lab at Natick to revise the specification for internal pressure test and allow a larger plate gap with a reduced pressure requirement:.

4.5.6 Internal pressure test. Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates. The plates shall be 1/2 inch ± 1/16 inch apart or 1 inch ± 1/16 inch apart for SSP, or 2 inches ± 1/16 inch apart for ISP. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously. For SSP, the pressure shall be 20 psig for the 1/2 inch plate distance and 12 psig for the 1 inch plate distance. For ISP, the pressure shall be 20 psig for the 2 inch plate distance. Pressure shall be applied gradually until pressure set point is reached. The pressure set point shall be held constant for 30 seconds and then released. The pouches shall then be examined for separation or yield of the seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure and shall be cause for rejection of the lot.

3.3.1 Plant Floor Implementation

Based on the proposed change in specification, Ameriqual was asked to perform a side by side comparison of the four sides seal test with a 1" gap distance and 12 psig for 30 seconds versus and a three sided seal test that was set up with a plate gap of 0.5" and a pressure setting of 20 psig for 30 seconds. A total of 177 lots were tested and similar accept/reject rates were obtained using both test methods. This confirmed the validity of the model and lead to the acceptance by the military to allow the four sided seal test with a 1" gap and a 12" internal pressure setting for 30 seconds..

3.4 Cost Benefit Analysis

The cost benefit for this project be quantified as follow:.

- An average of 3572 lots are produced annually (USDA inspection data MRE20-MRE-25).
- The test cost of a thermal stabilized MRE is: $1.50/pouch including labor
- 50% of the lots are manufactured using the HFFS pouch technology (USDA MRE 24 - MRE 25 data), hence 1786 lots. .
- Assume that 48 pouch seals/lot are tested in-process for seal strength by the manufacturer if the HFFS technology is used.
    - 3 sided tester: 1786 lots/year x 48 test/lot x 2 pouch/test = 171,456 pouches/year
    - 4 sided tester: 1786 lots/year x 48 test/lot x 1 pouch/test = 85,728 pouches/year
    - Savings: 85,728 pouches/year
- Assume that 24 pouch seals/lot need to be tested in-process for seal strength by the manufacturer if the Vertical pouch technology is used
    - 3 sided tester: 1786 lots/year x 24 test/lot x 2 pouch/test = 85,728 pouches/year
    - 4 sided tester: 1786 lots/year x 24 test/lot x 1 pouch/test = 42,864 pouches/year
    - Savings: 42,864 pouches/year
- Assume that 8 pouch seals need to be tested from each lot for end item inspection by both the manufacturer and USDA. (S2 sampling plan). Further assume that for end item inspection a single IP test requirement means that two pouches have to be used in a three sided seal tester to test all four seals and that only one pouch has to be tested in a four sided seal tester. This test is performed by both the producer and the vendor. Hence, for end item inspection the total number of pouches used:
    - 3 sided tester: 3572 lots x 16 pouches/lot x 2 org. = 114,304 pouches
    - 4 sided tester: 3572 lots x 8 pouches/lot x 2 org. = 57,152 pouches
    - Savings: 57,152 pouches
- Using the four sided seal tester, the savings in pouches to be tested would be: 185,744 pouches (=85,728+42,864+57,152). Using a test cost of $1.50/test (labor and materials), this would lead to a savings of $278,616 annually.
- Assuming a project cost of $150,000, this would mean a payback within 7 month

3.5 Institutional Pouch

The current specification for the ISP requires an internal pressure test at 20 psig while the pouch is confined between two plates with a 2" gap. As was determined in the first part of this research work, all the ISP's for retort application will fail around 15-17.5 psig (TWP#223). These pouches were, however, tested by the military and found to have adequate seal strength to survive the military distribution system. Hence, the internal pressure specification does not reflect the actual performance requirement. Therefore, a revised specification needs to be developed based on underlying performance standards that need to be met, being the drop test and the vibration test.

The results associated with this work are reported in Technical working paper TWP#224 and summarized in this section.

3.5.1 Lab Testing

In cooperation with the Natick research lab, who have an electronic controlled sealer, water filled ISP pouches were produced and retorted. Seal conditions were set in an operating range that would create weak seals. The product was then packed in sleeves and cased according to the packaging specification. The cases were then exposed to the required 10 drop test and the vibration test. Pouches that passed were then tested for burst strength. Detailed results of the protocols used and the test results are reported in technical working paper (TWP) 224.

3.5.2 Recommendation

Based on this study, recommendations were made to Natick Lab to lower the internal pressure requirement for the ISP from 20 psig to 10 psig, using a 2" plate gap. It should be noted that this pressure setting is a more demanding seal strength requirement than required from an MRE pouch. The higher seal strength requirement is due to the larger hydraulic forces that are involved during shipment abuse of the ISP.

It is recommended to change the specification for internal pressure testing in specification document MIL-PRF-44073G to read:

4.5.6 Internal pressure test. Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates. The plates shall be 1/2 inch ± 1/16 inch apart or 1 inch ± 1/16 inch apart for SSP, or 2 inches ± 1/16 inch apart for ISP. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously. For SSP, the pressure shall be 20 psig for the 1/2 inch plate distance and 12 psig for the 1 inch plate distance. ***For ISP, the pressure shall be 10 psig for the 2 inch plate distance.*** *Pressure shall be applied gradually until pressure set point is reached. The pressure set point shall be held constant for 30 seconds and then released. The pouches shall then be examined for separation or yield of the seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure and shall be cause for rejection of the lot.*

4 Appendix:

4.1 Technical Working Paper 223: "Four Sided Seal Tester Test Data & Data Analysis"

4.2 Technical Working Paper 224: "Internal Pressure Protocol for Institutional Sized Pouches"

COMBAT RATION NETWORK
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Four Sided Seal Tester
Test Data & Data Analysis

Technical Working Paper (TWP) #223

Henderikus Bruins

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9/15/07

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Index

1. Introduction

Current specifications for pouches (MIL-PRF-44073F) require that the seals of pouches are tested via an internal pressure test to validate that the seals resist a minimum internal pressure of 20 psig for 30 sec, while the pouch is constraint between two plates. Two test methods are allowed, the most common one being the three sided seal tester and as an alternate a four sided seal tester.

The four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) can be used, in which all four seals can be tested simultaneously. The advantage of the four seal tester is that only one pouch needs to be used for testing all four seals and that the content of the pouch does not have to be removed. The content of the pouch can therefore be used for another Quality Assurance test after completion of the internal pressure test. This makes the four sided seal tester more cost effective and faster than the three-seal tester.

However, the test protocol for the four sided seal tester requires that the plates distance is set at ½" for MRE pouches, while the filled retorted pouch thickness might range from 5/8" to 7/8" and pre-retorted pouches might be 1" thick or more. This makes the four sided seal test methodology not feasible, as the pouch can often not be compressed down to the ½" thickness.

Increasing the gap of the confinement plates is being proposed. However, this will also increase the forces that are created on the seal by the internal pressure of the pouch. It is estimated that doubling the gap from ½" to 1" gap could double the force on the seal. To reduce the force on the seal, the internal pressure would need to be reduced accordingly.

The test methodology for Institutional Sized Pouch specifies a plate distance of 2", while maintaining the same internal pressure requirements (20 psig for 30 sec). Industry members that have tested ISP at these conditions have remarked that pouches consistently fail at these conditions, thus supporting the hypothesis that there is a relationship between the internal pressure applied, the distance between the two confinement plates and the seal strength of the pouch

Developing this relationship between internal pressure, the plate distance and seal strength will allow testing of pouches in a four sided seal tester, a method that is significantly faster (pouches don't have to be emptied) and requires less pouches than the three side tester and will result in a cost savings.

2. Objective:

Test Pouches from various vendors and determine burst strength as function of the distance between confinement plates. Test the same pouches for seal strength and develop an empirical model(s) that correlate the burst strength and seal strength as function of the confinement plate distance.

3. Theoretical Analysis

Two distinctive states of stress occur in the pressurized pouch depending on the seal location whether it is on the pouch straight edge or at the curved part at the pouch corner as well as the transition zone between these two regions, In the next two sections will will analyze the stresses in symmetric pouches. In the third section we will review the stresses in unsymmetrical pouches which occur when horizontal form fill and seal technology is used.

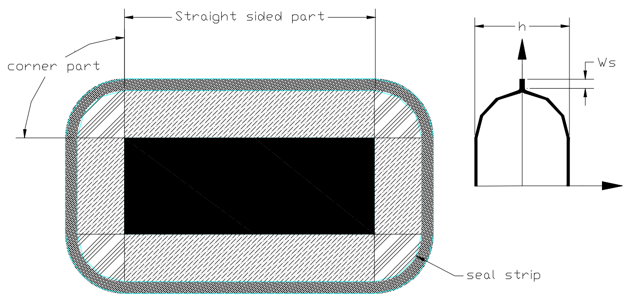


Figure1. Schematic view of the pouch and seal geometry

3.1. Stress Analysis of the Straight Edge

From equilibrium of an element of 1 inch thickness at an angle θ,

$$dF_y = (p.R.d\theta)\sin\theta$$

$$dF_x = (p.R.d\theta)\cos\theta$$

$$F_y = \int_{\theta=0}^{\theta=\pi/2}(p.R.d\theta)\sin\theta$$

$$= pR\int_{\theta=0}^{\theta=\pi/2}\sin\theta d\theta = pD/2$$

The film peeling force per unit length

$$F_p = \frac{pD}{2} = \left(\frac{ph}{2}\right) \quad lb/inch$$

The film hoop stress σ_θ *is given by*:

$$\sigma_\theta = \frac{pD}{2t} \quad psi$$

$$Hence, \sigma_x = \sigma_y = \left(\frac{pD}{2t}\right) = \left(\frac{ph}{2t}\right) - - - - - (1)$$

where "h" is the platten seperation gap

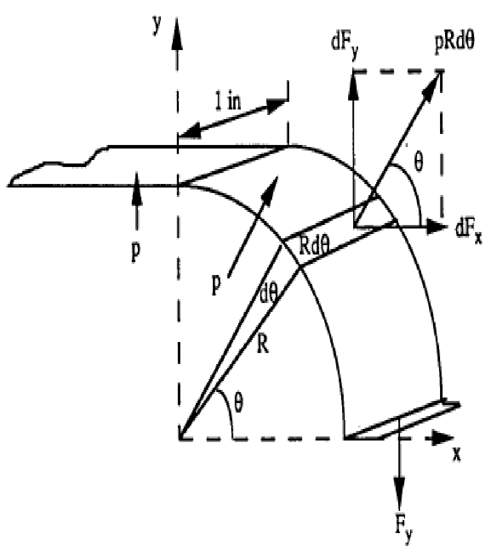


Figure 2:. Force Analysis on Straight Part

3.2. Stress Analysis of the Curved Part

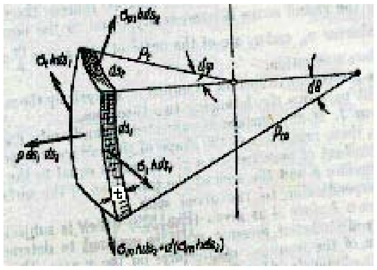
The stress state can be determined from equilibrium of a sector at an angle θ and ϕ of a typical symmetrical shell analysis as shown in Figure 3

Since the pouch corner may be considered as part of a symmetrical shell of a spherical shape then an element of the shell having its side length ds_1 is subjected to meridian stress σ_m and the side width ds_2 is subjected to circumferential stress σ_t. Thus, from equilibrium of the element under internal pressure "*p*" and by projecting all forces on the normal to the element Figure 3. Curved Part Analysis
we get:

$$p.ds_1.ds_2 - \sigma_m.t.ds_2.d\theta - \sigma_t.t.ds_1.d\phi = 0, \text{ since}$$

$$d\theta = \frac{ds_1}{\rho_m}, \quad d\phi = \frac{ds_2}{\rho_t}, \quad \text{then,}$$

$$\frac{\sigma_m}{\rho_m} + \frac{\sigma_t}{\rho_t} = \frac{p}{t}$$



Therefore, in the case of a spherical shell, and from Laplace equation

Figure3

$$\sigma_m = \sigma_t = \frac{\rho}{2t} \;\; and \quad \rho = R = D/2 = h/2$$

Hence;

$$\sigma_m = \sigma_t = \left(\frac{pD}{4t}\right) = \left(\frac{ph}{4t}\right)$$

Since there are no shear stresses, then σ_m *and*, σ_t are principal stresses and hence;

$$\sigma_1 = \sigma_2 = \frac{pD}{4t} = \left(\frac{ph}{4t}\right) - - - - - (2)$$

$$\sigma_3 = -p$$

Since σ_3 =-p is too small compared with σ_1, then the yield stress according to Tresca, yield criterion in spherical shell may be given by:

$$\sigma_Y = \left(\frac{ph}{4t} - (-p)\right) = \left(\frac{ph}{4t}\right)$$

which is half the value of the cylindrical shell. This explains why that the film failure occurs at the straight sided parts of the pouch and not at the corners

3.3. Unsymmetrical Pouch Analysis

Horizontal Form Filled and Sealed Pouches are unsymmetrical in which the length of the pouch film of the bottom half is longer than the length of the top film. This causes the seal to be located in an unsymmetrical position , however from equilibrium of forces on a pouch segment placed at the pouch straight side, Figure 4, we get:

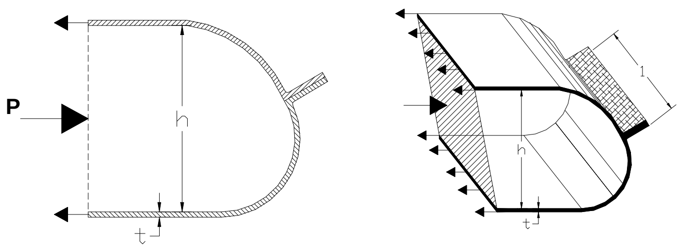


Figure 4

$$2\sigma_t \cdot 1 \cdot t - p \cdot 1 \cdot h = 0$$

$$\sigma_t = \left(\frac{ph}{2t} \right) --------3$$

Equation (3) is similar to that of straight edge symmetric pouch analysis, the unsymmetrical pouch curvature is due to deformation constrains imposed by the relative rigidity of the seal ridge

3.4. Theoretical Model for Burst Pressure in Symmetrical Pouches

Based on the above analysis, we concluded that the forces on the seal are the greatest in the straight section of the seal and that the relationship between plate distance and internal pressure is given by

Fs=p x D / 2, where
Fs: Force on the Seal
P: internal pressure of pouch
D: Distance of the confinement Plates

Assuming that the pouch fails when the Force on the seal exceeds the peak seal strength we can state that

$F_{peel} = p_{burst}$ x D / 2

Or

p_{burst1} x D_1 / 2 = p_{burst2} x D_2 / 2 or

p_{burst2} / p_{burst1} = D_1 / D_2

If we use this relationship and assume a 20 psig internal pressure requirement for plate distances of 0.5”, the following pressure settings for plate distances that are greater then 0.5” should yield similar accept/reject rates based on this theoretical model:

0.5”	20 psig
0.75”	13.3 psig
1.00”	10 psig
1.25”	8 psig
1.50”	6.7 psig
2.00”	5 psig

4. Experimental Phase

In the following sections we will review the experimental data that was collected from both burst tests and seal strength test. Based on this experimental data, we will develop an empirical model and compare this to the theoretical model.

4.1. Materials:

The following pouches were tested:

- Horizontal Form Fill Seal, 8 oz MRE sourced from Ameriqual
- Horizontal Form Fill Seal, 5 oz MRE sourced from Ameriqual
- Horizontal Form Fill Seal, 8 oz MRE sourced from the CORANET Demo Site
- Preformed MRE, 8 oz, sourced via Ameriqual, sealed by Demo Site
- Preformed MRE, 5 oz, sourced via Ameriqual, sealed by Demo Site
- Preformed MRE, 8 oz, sourced by Demo Site and sealed by Demo Site
- HFFS Bakery Pouch, Hoaah Bar, sourced from Sterling
- HFFS Bakery Pouch, Fig Bar, sourced from Sterling
- HFFS Bakery Pouch, Sports Bar, sourced from Sterling
- HFFS Bakery Pouch, Snack Bread, sourced from Sterling
- Institutional Pouch, sourced from Demo Site, sealed by Demo Site
- Institutional Pouch, sourced from Natick, sealed by Demo Site

4.2. Sample Preparation

The Bakery pouches were filled and sealed by Sterling Foods and tested “as is” without removing the content of the pouch.

All other pouches were retorted pouches that were filled with a paper towel to ensure distance between the two sides of the pouch so that a needle could be inserted through one side of the pouch and inflate the pouch with air. The Horizontal Form Fill Seal pouches were sealed by the respective sourcing company on their commercial line, using standard sealing conditions used for production. The vertical preformed pouches were filled and sealed at the Demo Site using either a heat bar sealer (MRE) or an impulse sealer (ISP). A random selection of these pouches were tested for seal strength. The remaining pouches were retorted at 250 F for 60 minutes. All pouches were allowed to equilibrate for 72 hrs before being tested for seal strength or burst strength. The temperature at which the samples were tested was maintained at 74 F +/- 4 F.

4.3. Peel Strength Protocol:

Seal Samples (1” width and 2” long tails) were cut from the pouch seal area. The tails were clamped in the yaws of the Chatillon seal strength tester (initial distance of yaws: ¾”). The yaws were then separated at a speed of 12”/min until failure of the seal occurred. The stress strain curve was recorded as well as the maximum force and energy required to cause seal failure.

4.4. Burst Strength Protocol:

Each pouch was inflated till burst occurred, using four different plate distances. The plate distance for MRE sized pouches was set at: 1/2”, ¾”, 1” and 1-1/4”. The plate distance for Institutional Pouches was set at ½”, 1”, 1.5” and 2”. Pouches were inflated to a starting pressure that was at least 5 psig lower then the pressure at which burst occurs at the largest plate distance and held for 30 second. The pressure was increased in steps of 5 psig (ramp ~ 1 psig/sec) and held for 30 sec at each incremental pressure step. This process was repeated until burst occurred. The pressure at which the burst occurred was recorded as well as the time of failure and the location of the seal rupture. If the burst occurred during the pressure ramp, the last hold pressure plus 2.5 psig was recorded. The test was replicated at least 5 times for each pouch type and confinement plate distance.

4.5. Test Results:

The peel strength data and burst strength data is summarized and tabulated in the appendix. As expected, we observed that the peel strength of a retorted pouch weakens after the retort process. Also, as expected, we observed that the burst strength of a pouch diminishes as the distance of the confinement plates increases. We also observed that the burst strength of a pouch is influenced by the temperature to which the pouch is acclimated and/or tested. The effect of temperature variation is a cause of induced variation in the data of the MRE Retort and Bakery Pouches. Care was taken during the burst testing of the ISP pouch that the effect was minimized.

4.6. Data Analysis

In this section we will analyze the test results and build correlation models that describe

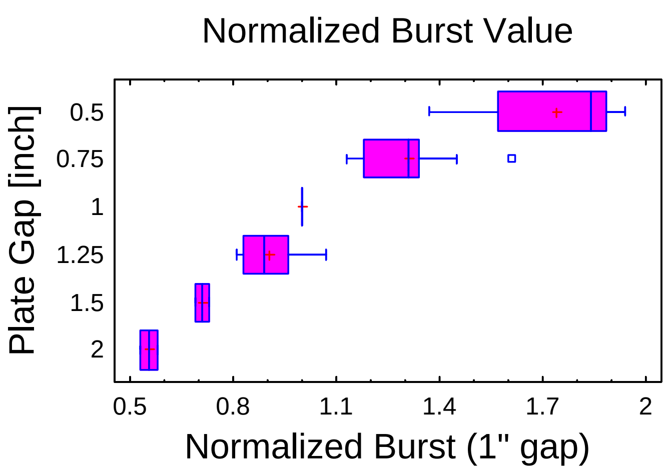
a) the interaction between burst pressure and confinement plate distance
b) the interaction between peel strength and burst pressure at one selected plate distance

4.6.1. Burst Pressure Normalization

Because the seal strength and burst pressure of the various pouches differs, the burst pressures values of each pouch type needed to be normalized in order to allow comparison of data among the different type pouches. Normalization was accomplished by determining the ratio of the average burst pressure at the different plate gaps versus the average burst pressure for a 1" gap. This normalized data was then used to develop the empirically relationship of the burst pressure as function of plate distance. The results of this normalization can be seen in the table below

Summary Statistics

Code	Count	Average	Median	Standard Deviation
0.5	12	1.74083	1.84	0.214623
0.75	10	1.311	1.31	0.141692
1	12	1.0	1.0	0.0
1.25	10	0.907	0.89	0.0813839
1.5	2	0.71	0.71	0.0282843
2	2	0.555	0.555	0.0353553
Total	48	1.2	1.0	0.386831

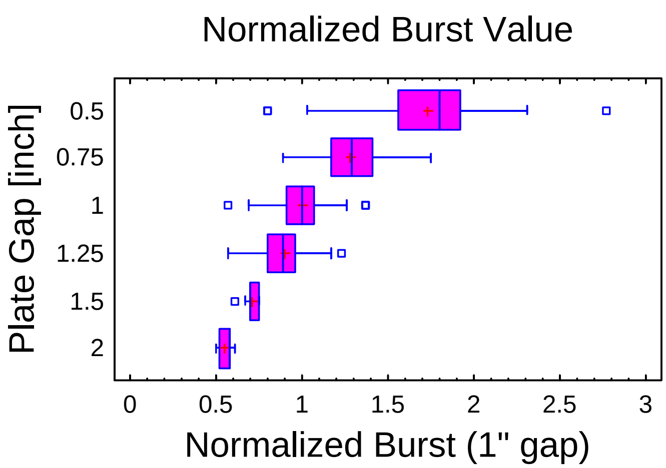


In the next section we normalized each individual burst pressure based on the average burst pressure for each pouch type at a 1" plate gap. Because the number of pouches tested for each pouch type was not equal, the data is somewhat biased to the pouch type that had the largest number of pouches tested (retort pouches)

Summary Statistics

Code	Count	Average	Median	Standard Deviation
0.5	113	1.73292	1.8	0.324752
0.75	94	1.28309	1.29	0.195904
1	113	0.999646	1.0	0.134542

1.25	91	0.899341	0.89	0.121863
1.5	19	0.713158	0.7	0.0384495
2	19	0.552105	0.58	0.0344124
Total	449	1.19214	1.08	0.413898

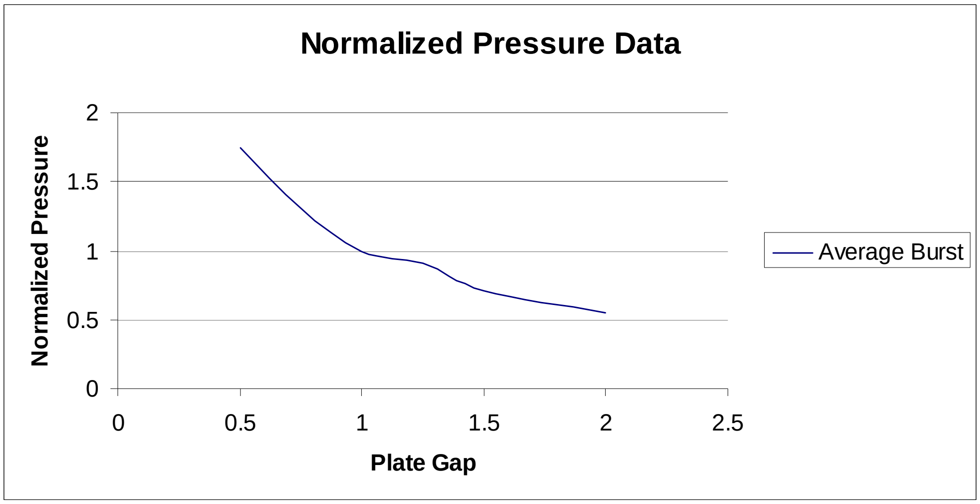


4.6.2. Burst Pressure Modeling

To keep the impact of various pouch types equal on the overall model, we based the following modeling on the normalized average burst strength of each pouch type.

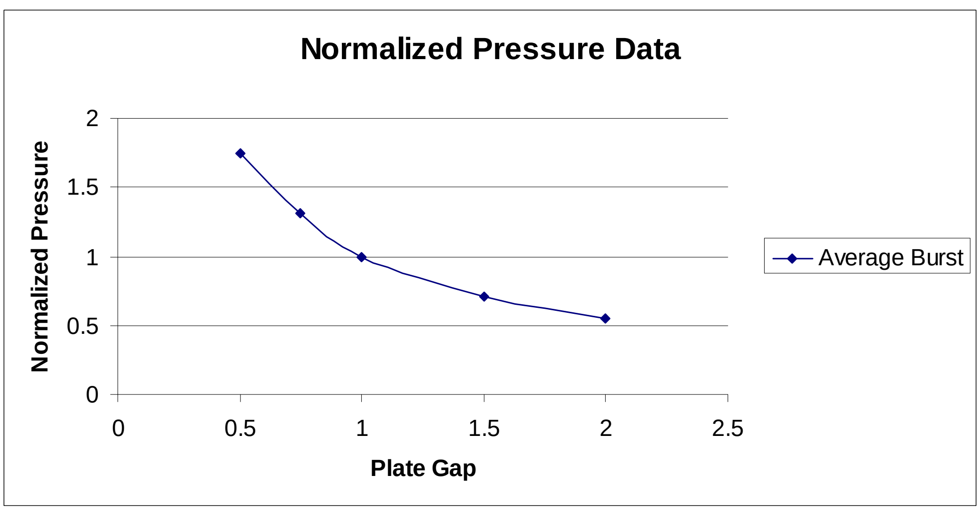
4.6.2.1. Pouch Size vs Plate Distance

The graph below relates the median normalized burst pressure data to the gap of the confinement plates. As we can see, the median burst pressure data seems to deviates from expectation at the 1-1/4” confinement plate distance.



This deviation in data might have been caused by the fact that less than 60% of the pouch is in contact with the confinement plates, a condition that should be avoided as mentioned in the ASTM-F-2054 Appendix X1.3.

In the following data set, we have excluded the 1-1/4” plate distance for all MRE pouches and also excluded the 1” data from the Hooah, Fig and Sports Bar. These pouches are narrow and fall below the minimum 60% contact area at a plate distance of 1”. The resulting median burst pressure data can be seen in the graph below.



4.6.2.2. Regression Analysis

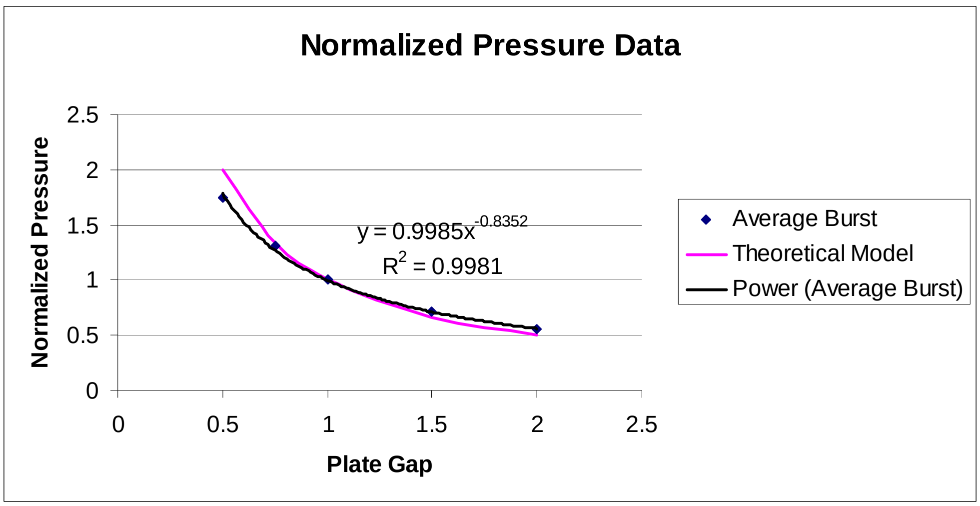
The graph below depicts the results of the regression analysis between the medium normalized burst pressure data and the gap of the confinement plates. The best fitted model is a power function:

P_{normal}=0.9985* (Plate Gap)$^{-0.8352}$.

The R2 value for this model is 0.998.

Other models such as linear, logarithm, polynomial and exponential all yielded a lower R2 value.

As comparison, we also added the theoretical model (P_{normal}=1*(Plate Gap)$^{-1}$. As we can see, the actual burst pressure data indicates a slightly lower impact of the plate distance on burst pressure than Dr Yam model predicts at narrow plate distances. Therefore, the experimental model is more conservative and should be used



Using the above empirical model, we developed the following proposed change in test methodology:

Four Sided Seal tester can be used with an adjustable plate distance for pouch confinement under the condition that at least 60% of the pouch is in contact with the plate. Contact area can be calculated based on the following formula:

Z=((x-(Π*D/2))/D)*100, where

x= the lesser value of the internal pouch width or length,

D= Plate gap

Z=percentage package surface in contact with restraining plates

Based on a 20 psig pressure requirement for plate distances of 0.5”, the following pressure settings for plate distances that are greater then 0.5” should yield similar accept/reject rates, assuming that more than 60% of the pouch remains in contact with the confinement plates:

0.5”	20 psig for 30 sec
0.75”	15 psig for 30 sec
1.00”	12 psig for 30 sec
1.25”	10 psig for 30 sec
1.50”	8 psig for 30 sec
2.00”	7 psig for 30 sec

Based on a 14 psig pressure requirement for plate distances of 0.5” (Bakery Pouches), the following pressure settings for plate distances that are greater then 0.5” should yield similar accept/reject rates, assuming that more than 60% of the pouch remains in contact with the confinement plates:

0.5”	14 psig for 30 sec
0.75”	10 psig for 30 sec
1.00”	8 psig for 30 sec
1.25”	7 psig for 30 sec
1.50”	6 psig for 30 sec
2.00”	5 psig for 30 sec

4.7. Proposed Changes in Military Packaging Specification

Because the experimental model is more conservative than the theoretical model, the proposed changes in military packaging specification are based on the empirical model.

4.7.1. Current Specification for Internal Pressure Test.

Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates. The plates shall be spaced 1/2 inch ± 1/16 inch apart for SSP and 2 inches ± 1/16 inch for ISP. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously. Pressure shall be applied ~~at the approximate uniform rate of 1 psig per second~~ gradually until 20 psig pressure is reached. The 20 psig pressure shall be held constant for 30 seconds and then released. The pouches shall then be examined for separation or yield of the heat seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure.

4.7.2. Proposed Revision of the Internal Pressure Test.

Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates. The plates shall be at least 1/2 inch ± 1/16 inch apart and not more than 1 inch for MRE or 2 inches ± 1/16 inch for ISP. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously and the plate distance can be set at 0.5", 0.75", 1.00", 1.25", 1.50" or 2.00" but never set to less than 1/16" wider than the thickness of the pouch. The test pressure set point is a function of the plate distance and should be set at 20, 15, 12, 10, 8 or 7 psig respectively to the above plate gaps. If a plate distance is used that differs from the above mentioned recommended plate distances, the pressure set point of the nearest narrower gap should be used. Pressure shall be applied gradually until pressure set point is reached. The pressure set point shall be held constant for 30 seconds and then released. The pouches shall then be examined for separation or yield of the heat seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure.

4.8. Correlation between Seal Strength Data and Burst Pressure

Because the burst value is determined by the weakest section of the pouch seal, the correlation between burst pressure and seal strength needs to be based on the minimum seal strength and not on the average seal strength. The median of the minimum seal strength data for each pouch was used and correlated to the median burst pressure data. The burst pressure values at a 1" gap distance were used for this correlation study.

The seal strength data for this correlation study was converted to [lbf/inch] and the summary data can be seen in the table below. As can be seen the minimum seal strength data varied from10 lbf/inch for pouched Bread to 28 lbf /inch for a MRE retorted pouch. It can also be seen that the HFFS MRE pouches had a significant lower minimum peel strength ~ 15 lbf/inch than the preformed MRE and ISP pouches.

Pouch Type	Count	Average Minimum Seal Strength [lbf/inch]	Median Minimum Seal Strength [lbf/inch]	Standard Deviation [lbf/inch]
Alcan 8 oz	12	24.525	24.5	1.36723
Fluter 5 oz	6	28.1333	28.7	1.50953
Fluter 8 oz	6	26.45	27.4	2.01172
HFFS, 5 oz AMQ	5	16.14	13.7	4.65489
HFFS, 8 oz AMQ	5	16.7	16.4	2.22036
HFFS, 8 oz, RUT	6	15.85	15.9	0.900555
Fresco ISP	4	23.45	23.55	1.12694
Jap ISP	4	20.7	20.75	0.469042
Hoaah	5	19.86	19.8	0.850294
Fig	5	15.08	15.7	2.00175
Sports	5	11.32	11.4	0.622093
Bread	5	10.24	10.3	0.934345
Total	68	19.7088	20.2	5.90157

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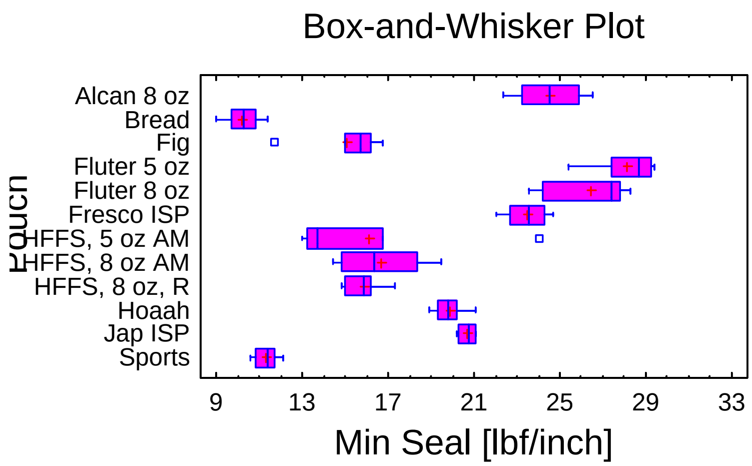

The table below summarizes the burst pressure data for each of the pouch types that have been evaluated. As can be seen, the burst pressures at 1" plate gap distances varied from 20 psig for Bakery pouches to around 40 psig for preformed MRE retort pouches (post retort). The burst strength of the ISP pouches was around 30 psig, while the HFFS pouches failed around 25 psig while confined at 1" distance

Burst Pressure Summary Statistics
Plate Gap = 1"

Pouch Type	Count	Average Burst Pressure [psig]	Median Burst Pressure [psig]	Standard Deviation [psig]
Alcan 8 oz	12	38.5417	40.0	1.9824
Floeter 5 oz	12	43.75	42.5	10.6867
Floeter 8 oz	12	36.4583	37.5	8.15046
HFFS, 5 oz AMQ	11	21.8182	20.0	2.75928
HFFS, 8 oz AMQ	11	27.9545	27.5	2.6968
HFFS, 8 oz, RUT	12	25.0	25.0	3.19801
Fresco ISP	9	28.6111	30.0	2.20479
Jap ISP	10	30.0	30.0	1.17851
Hoaah	6	28.75	28.75	5.18411
Fig	6	22.9167	23.75	2.45798
Sports	6	21.25	20.0	2.09165
Bread	6	19.1667	20.0	1.29099
Total	113	29.9336	30.0	8.84174

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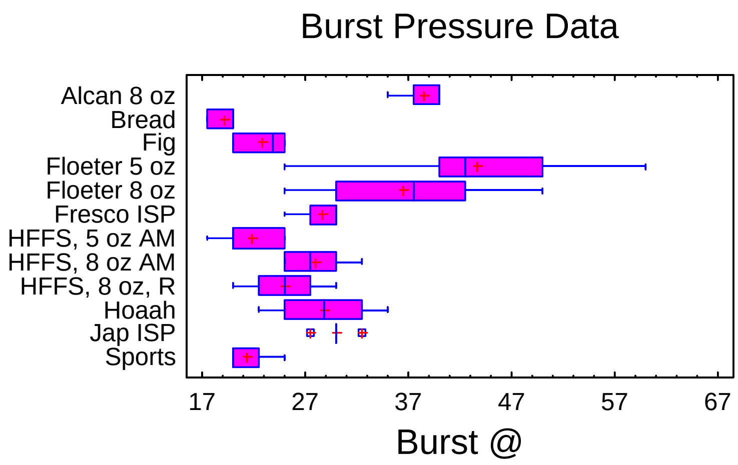
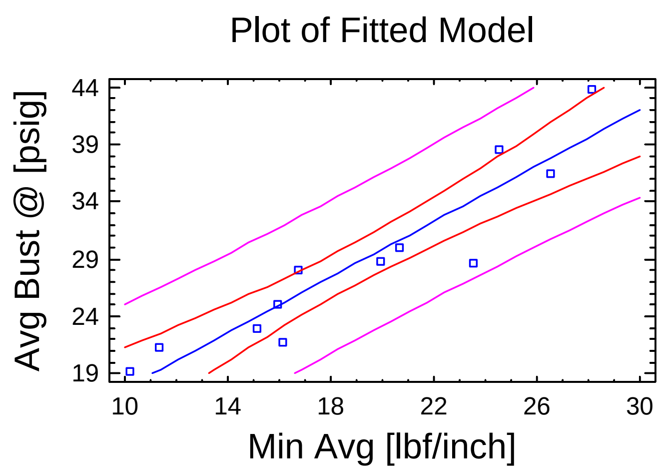
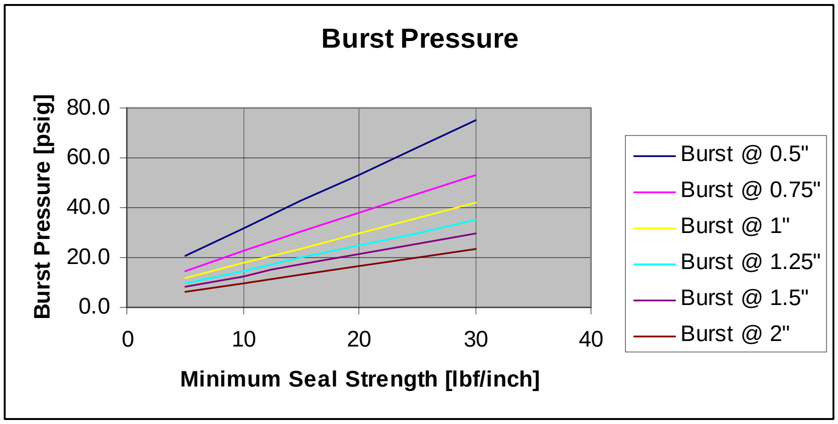


A simple linear regression analysis was performed between the average minimum seal strength and the average burst pressure The resulting model was:

Average Burst @ 1” Plate Gap = 5.5522 + 1.21564* Minimum Seal Strength [lbf/inch]
Correlation Coefficient = 0.93



The combination of the regression model of the peel strength data and the burst pressure data and the model between burst pressure data and plate gap was used to construct the following table which graphically shows the expected burst pressure value as function of the minimum seal strength data and confinement plate distance.



4.9. Case Studies

Having determined the best fitted models between burst pressure, confinement plate distance and peel strength data, we can predict pouch behavior when one of these variables changes. Three case studies are presented:

Case Study #1:

Using a 1” confinement plate distance and assuming that we want the pouch not to burst at 15 psig, but 20 psig burst is acceptable. What does the Minimum Median Seal Strength needs to be?
Burst Pressure: 20 psig at Plate Distance 1”,

Hence: Minimum Peel Strength.= (Burst Pressure – 5.63525) / 1.21594 = 11.8 lbf/inch

Case Study #2:

A pouch has a 5 lbf/inch minimum seal strength. At what pressure will this pouch burst using a 1.0 inch confinement plate distance and a 0.5” confinement plate distance?

Burst Pressure @ 1” = 5.63525 + 1.21594 * Minimum Seal Strength = 11.7 psig

Burst Pressure @ 0.5” = 0.9848 * Gap^-0.8412 * Burst Pressure @ 1” = 20.6 psig

Case Study #3:

A pouch fails the burst test using a ¾” plate distance at 20 psig, but passes the 15 psig internal pressure test. Does this pouch meet the Military specification?

Burst Pressure @ (Gap=0.75”) = 0.9848 * Gap^-0.8412 * Burst Pressure @ 1”
Hence the Burst Pressure @ 1” is 15.9 psig and expected to pass at 12 psig at 1” Gap

Burst Pressure @ (Gap=0.50") = 0.9848 * Gap^-0.8412 * Burst Pressure @ 1"
Hence the Burst Pressure @ 0.5" is 28 psig and expected to pass at 21 psig at 0.5" Gap and thus meet military specifications

It is further estimated that the pouch has minimum seal strength of 8.4 lbf/inch.

Summary Data Table

Film Source	Pouch	Pack Line	Plate Gap [inch]	Avg Bust @ [psig]	Median Burst @ [psig]	STD [psig]	Norm Burst [-]	Tensile [N]	T-std [N]	Min Avg [lbf/inch]	Min Median [lbf/inch]	Min Std [lbf/inch]
Alcan	8 oz	R1	0.50	72.7	70.0	5.8	1.89	115	7	24.5	24.5	1.4
Alcan	8 oz	R1	0.75	50.4	50.0	4.0	1.31	115	7	24.5	24.5	1.4
Alcan	8 oz	R1	1.00	38.5	40.0	2.0	1.00	115	7	24.5	24.5	1.4
Alcan	8 oz	R1	1.25	31.3	30.0	2.0	0.81	115	7	24.5	24.5	1.4
AMQ	5 oz	HFFS	0.50	41.8	42.5	7.1	1.92	97	23	16.1	13.7	4.7
AMQ	5 oz	HFFS	0.75	29.1	30.0	3.4	1.33	97	23	16.1	13.7	4.7
AMQ	5 oz	HFFS	1.00	21.8	20.0	2.8	1.00	97	23	16.1	13.7	4.7
AMQ	5 oz	HFFS	1.25	20.8	20.0	1.7	0.95	97	23	16.1	13.7	4.7
AMQ	8 oz	HFFS	0.50	46.4	50.0	7.1	1.66	99	19	16.7	16.4	2.2
AMQ	8 oz	HFFS	0.75	31.6	30.0	5.6	1.13	99	19	16.7	16.4	2.2
AMQ	8 oz	HFFS	1.00	28.0	27.5	2.7	1.00	99	19	16.7	16.4	2.2
AMQ	8 oz	HFFS	1.25	25.3	25.0	3.0	0.90	99	19	16.7	16.4	2.2
Floeter	5 oz	R1	0.50	60.2	55.0	10.9	1.37	133	8	28.1	28.7	1.5
Floeter	5 oz	R1	0.75	51.3	50.0	8.8	1.17	133	8	28.1	28.7	1.5
Floeter	5 oz	R1	1.00	43.8	42.5	10.7	1.00	133	8	28.1	28.7	1.5
Floeter	5 oz	R1	1.25	36.5	35.0	6.2	0.83	133	8	28.1	28.7	1.5
Floeter	8 oz	R1	0.50	50.0	50.0	6.2	1.37	127	9	26.5	27.4	2.0
Floeter	8 oz	R1	0.75	46.7	45.0	8.1	1.28	127	9	26.5	27.4	2.0
Floeter	8 oz	R1	1.00	36.5	37.5	8.2	1.00	127	9	26.5	27.4	2.0
Floeter	8 oz	R1	1.25	35.0	35.0	6.2	0.96	127	9	26.5	27.4	2.0
Fresco	96 oz	IP-7	0.50	52.8	52.5	2.3	1.84	127	13	23.5	23.6	1.1
Fresco	96 oz	IP-7	1.00	28.6	30.0	2.2	1.00	127	13	23.5	23.6	1.1
Fresco	96 oz	IP-7	1.50	19.7	20.0	0.8	0.69	127	13	23.5	23.6	1.1
Fresco	96 oz	IP-7	2.00	15.3	15.0	0.8	0.53	127	13	23.5	23.6	1.1
Japanese	96 oz	IP-7	0.50	55.8	55.0	1.2	1.86	96	3	20.7	20.8	0.5
Japanese	96 oz	IP-7	1.00	30.0	30.0	1.2	1.00	96	3	20.7	20.8	0.5
Japanese	96 oz	IP-7	1.50	22.0	22.5	1.1	0.73	96	3	20.7	20.8	0.5
Japanese	96 oz	IP-7	2.00	17.3	17.5	0.8	0.58	96	3	20.7	20.8	0.5

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RUT	8 oz	HFFS	0.50	37.1	40.0	8.6	1.48	89	17	15.9	15.9	0.9
RUT	8 oz	HFFS	0.75	29.4	30.0	1.9	1.18	89	17	15.9	15.9	0.9
RUT	8 oz	HFFS	1.00	25.0	25.0	3.2	1.00	89	17	15.9	15.9	0.9
RUT	8 oz	HFFS	1.25	22.1	22.5	2.1	0.88	89	17	15.9	15.9	0.9
STE	Bread	HFFS	0.50	36.1	35.0	4.0	1.88	67	17	10.2	10.3	0.9
STE	Bread	HFFS	0.75	25.8	25.0	1.3	1.34	67	17	10.2	10.3	0.9
STE	Bread	HFFS	1.00	19.2	20.0	1.3	1.00	67	17	10.2	10.3	0.9
STE	Bread	HFFS	1.25	15.8	15.0	1.3	0.82	67	17	10.2	10.3	0.9
STE	Fig	HFFS	0.50	42.1	40.0	4.6	1.84	102	32	15.1	15.7	2.0
STE	Fig	HFFS	0.75	33.3	32.5	4.1	1.45	102	32	15.1	15.7	2.0
STE	Fig	HFFS	1.00	22.9	23.8	2.5	1.00	102	32	15.1	15.7	2.0
STE	Fig	HFFS	1.25	22.1	21.3	2.5	0.97	102	32	15.1	15.7	2.0
STE	Hoaah	HFFS	0.50	52.9	53.8	10.5	1.84	113	21	19.9	19.8	0.9
STE	Hoaah	HFFS	0.75	46.3	46.3	3.8	1.61	113	21	19.9	19.8	0.9
STE	Hoaah	HFFS	1.00	28.8	28.8	5.2	1.00	113	21	19.9	19.8	0.9
STE	Hoaah	HFFS	1.25	30.8	30.0	1.3	1.07	113	21	19.9	19.8	0.9
STE	Sports	HFFS	0.50	41.3	40.0	2.1	1.94	65	12	11.3	11.4	0.6
STE	Sports	HFFS	0.75	27.9	27.5	1.9	1.31	65	12	11.3	11.4	0.6
STE	Sports	HFFS	1.00	21.3	20.0	2.1	1.00	65	12	11.3	11.4	0.6
STE	Sports	HFFS	1.25	18.8	18.8	1.4	0.88	65	12	11.3	11.4	0.6

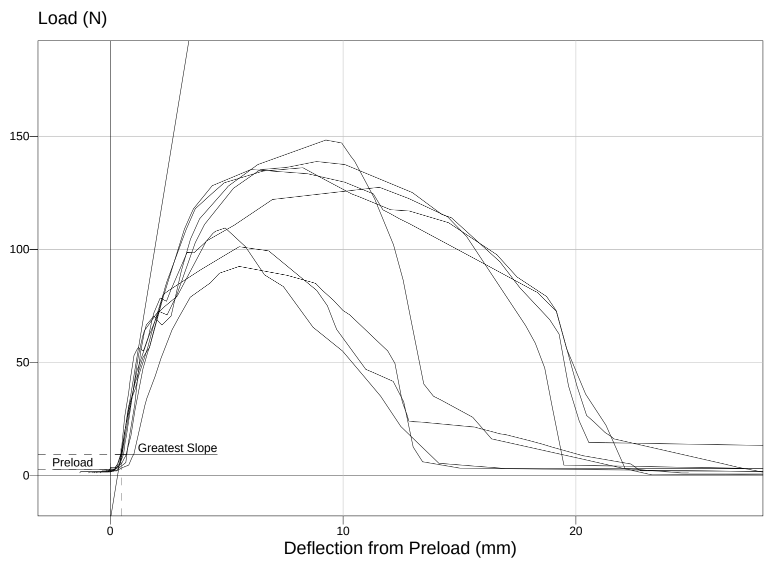
5. Appendix

Detailed Test Results of each individual pouch system

5.1. Horizontal Form Fill Seal, 8 oz MRE sourced from Ameriqual

Pouch Description
Pouch Size: 4-1/4” x 7-1/2” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

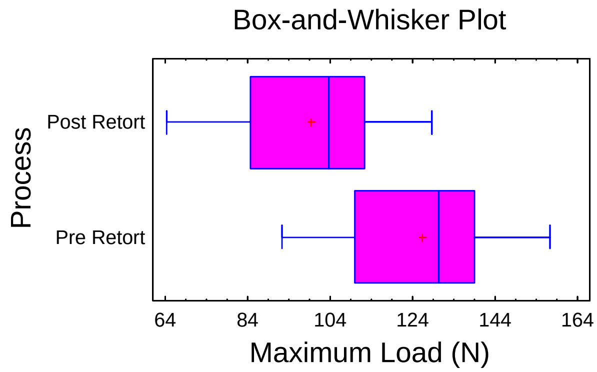
Seal Strength Data
Seal samples were taken from all sides of the pouch and from every pouch in the index



Stress/Strain Data from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	40	99.4272	103.55	19.1482
Pre Retort	32	126.41	130.485	16.7744
Total	72	111.42	109.885	22.507



Minimum Seal Strength Post Retort/Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

73 N/inch	64 N/inch	87 N/inch	66 N/inch	82 N/inch
16.4 lbf/inch	14.4 lbf/inch	19.5 lbf/inch	14.8 lbf/inch	18.4 lbf/inch

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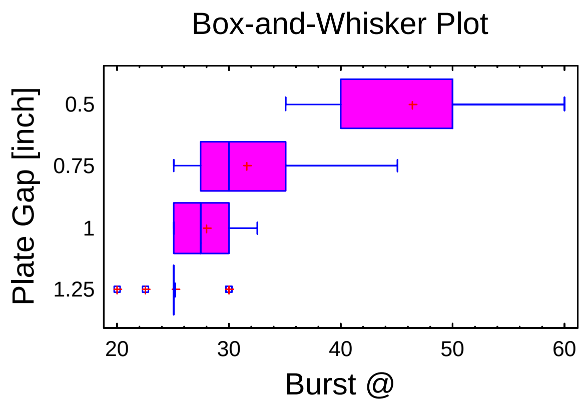
Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

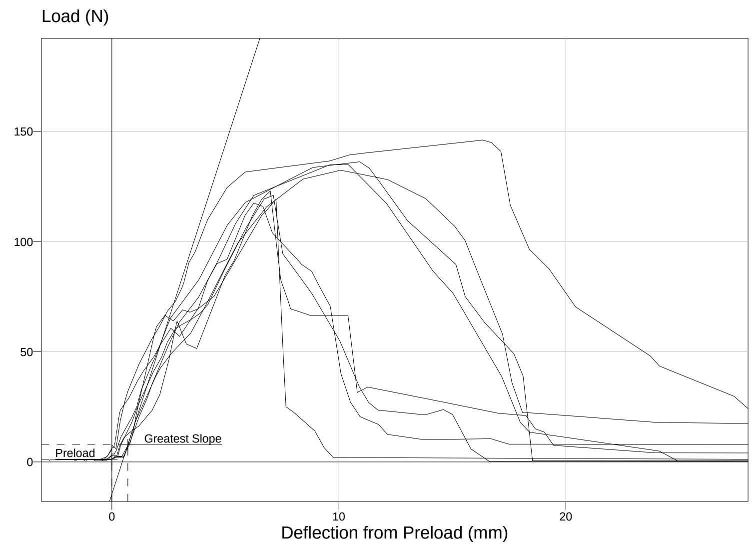
Plate Gap [inch]	Count	Average	Median	Standard Deviation
0.5	11	46.3636	50.0	7.10314
0.75	11	31.5909	30.0	5.62058
1	11	27.9545	27.5	2.6968
1.25	10	25.25	25.0	2.99305
Total	43	32.9651	30.0	9.5627


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
20
30
40
50
60
Burst @

5.2. Horizontal Form Fill Seal, 5 oz MRE sourced from Ameriqual

Pouch Description
Pouch Size: 44-1/4” x 5-1/2” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

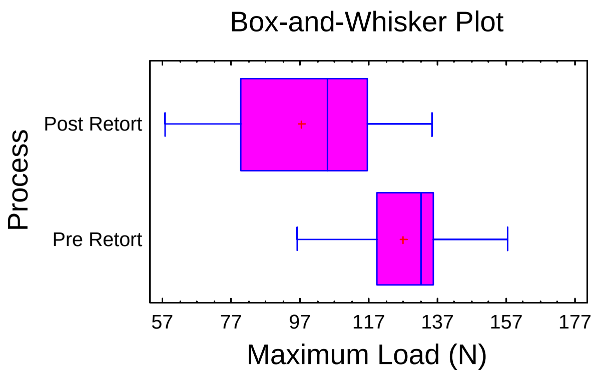
Seal Strength Data
Seal samples were taken from all sides of the pouch and from every pouch in the index



Stress/Strain Data from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	39	97.3541	105.0	22.8279
Pre Retort	24	127.056	132.135	15.7882
Total	63	108.669	110.31	24.9653



Minimum Seal Strength Post Retort/Pouch
The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

59 N/inch	107	75	61	58
13.2 lbf/inch	24	16.8	13.7	13.0

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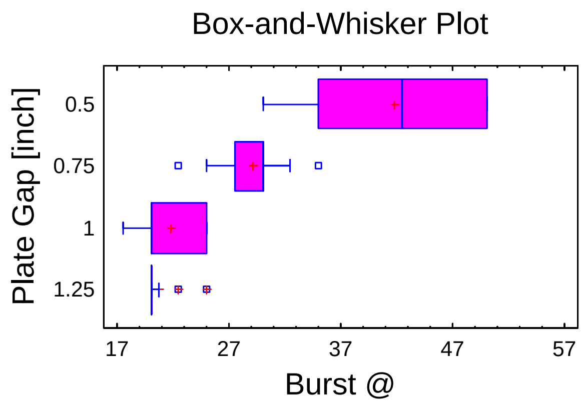
Burst Strength Data

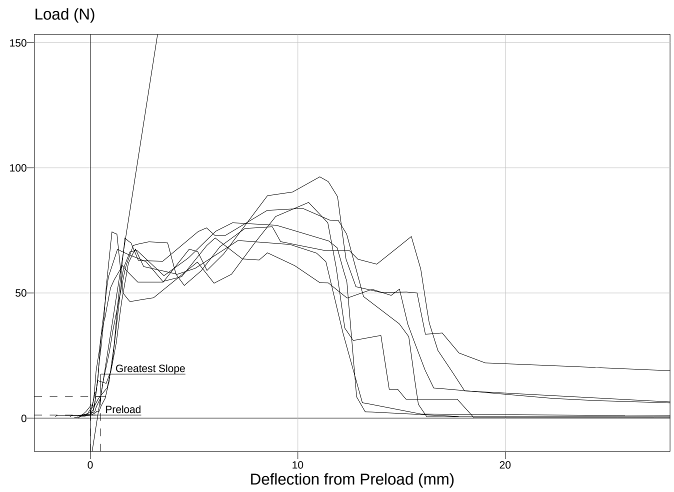
```
Summary Statistics of the pressure at which the pouch burst [psig]
                                                            Standard
Plate Gap [inch]     Count         Average       Median        Deviation
--------------------------------------------------------------------------
0.5                  11            41.8182       42.5          7.0791
0.75                 11            29.0909       30.0          3.40454
1                    11            21.8182       20.0          2.75928
1.25                 10            20.75         20.0          1.68737
--------------------------------------------------------------------------
Total                43            28.5465       25.0          9.4685
```


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
17
27
37
47
57
Burst @

5.3. Horizontal Form Fill Seal, 8 oz MRE sourced from the CORANET Demo Site

Pouch Description
Pouch Size: 4-1/4” x 7-1/2” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

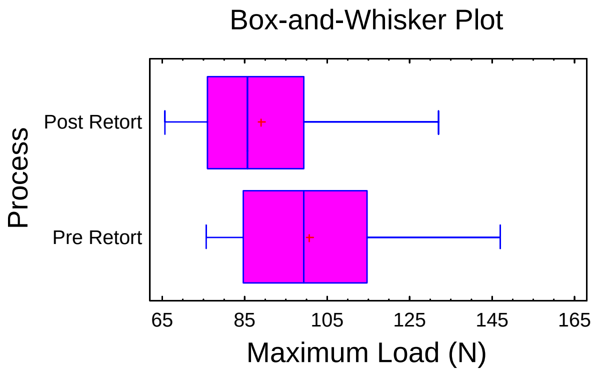
Seal Strength Data:
Seal samples were taken from all sides of the pouch and from every pouch in the index
.



Stress/Strain Curves from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	48	88.8652	85.5785	16.5028
Pre Retort	47	100.683	99.4655	18.739
Total	95	94.7117	91.9612	18.5281



Minimum Seal Strength Post Retort/Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

67 N/inch	72	71	82	71	66
15.0 lbf/inch	16.2	15.9	18.4	15.9	14.8

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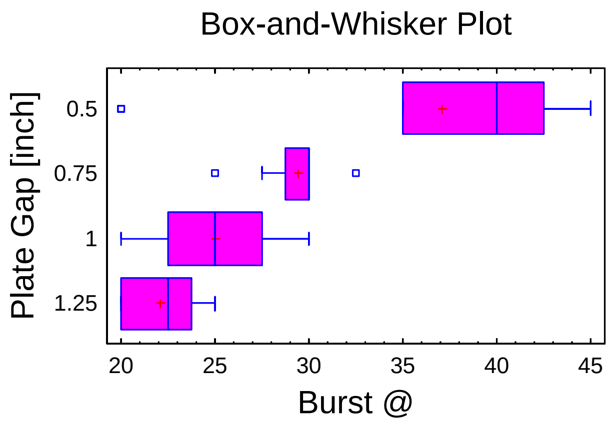
Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

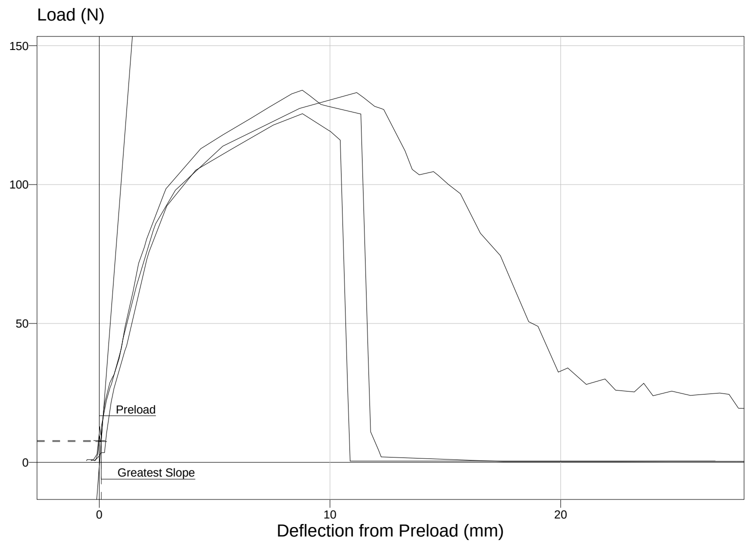
Plate Gap [inch]	Count	Average	Median	Standard Deviation
0.5	12	37.0833	40.0	8.64931
0.75	12	29.375	30.0	1.88445
1	12	25.0	25.0	3.19801
1.25	12	22.0833	22.5	2.08712
Total	48	28.3854	27.5	7.37465



5.4. Preformed MRE, 8 oz, sourced via Ameriqual, sealed by Demo Site

Pouch Description
Pouch Size: 4-1/4” x 7-1/4” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

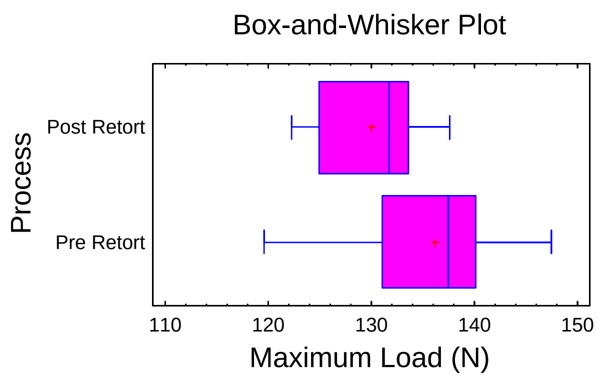
Seal Strength Data:
Three seal samples were taken from the Demo Site seal and none from the manufacturers seal. The Demo site seal was the weaker seal and more likely to fail during the burst test



Stress/Strain Curves from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	16	129.982	131.79	4.91602
Pre Retort	18	136.076	137.51	7.04655
Total	34	133.208	132.925	6.78925



Minimum Seal Strength Post Retort/Pouch
The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

108 N/inch	105	126	122	124	122
24.2 lbf/inch	23.6	28.3	27.4	27.8	27.4

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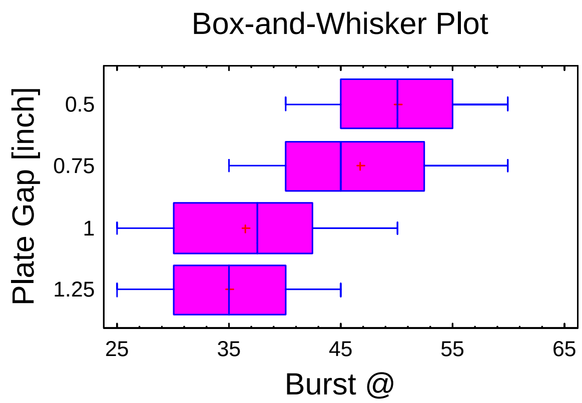
Burst Strength Data

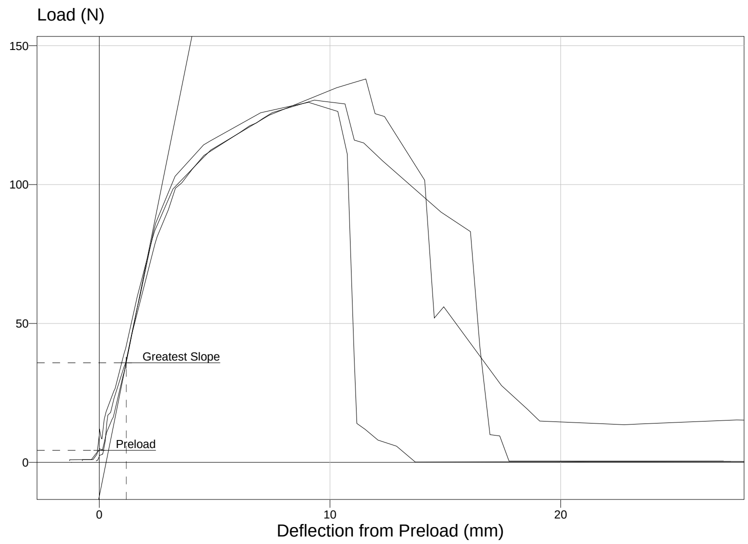
```
Summary Statistics of the pressure at which the pouch burst [psig]
                                                           Standard
Plate Gap [inch]     Count         Average       Median       Deviation
------------------------------------------------------------------------
0.5                  10            50.0          50.0          6.2361
0.75                 12            46.6667       45.0          8.07165
1                    12            36.4583       37.5          8.15046
1.25                 11            35.0          35.0          6.22495
------------------------------------------------------------------------
Total                45            41.8333       40.0          9.52568
```


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
25
35
45
55
65
Burst @

5.5. Preformed MRE, 5 oz, sourced via Ameriqual, sealed by Demo Site

Pouch Description
Pouch Size: 4-1/16” x 6-7/17” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

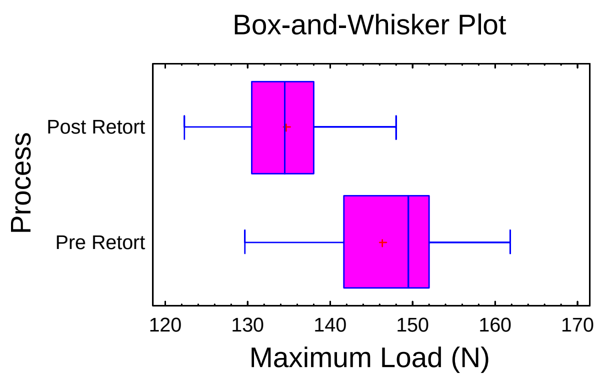
Seal Strength Data
Three seal samples were taken from the Demo Site seal and none from the manufacturers seal. The Demo site seal was the weaker seal and more likely to fail during the burst test



Stress/Strain Curves from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	17	134.684	134.42	6.70271
Pre Retort	18	146.394	149.46	8.43578
Total	35	140.706	138.59	9.59091



Minimum Seal Strength Post Retort/Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

128 N/inch	130	131	113	122	128
28.7 lbf/inch	29.2	29.4	25.4	27.4	28.7

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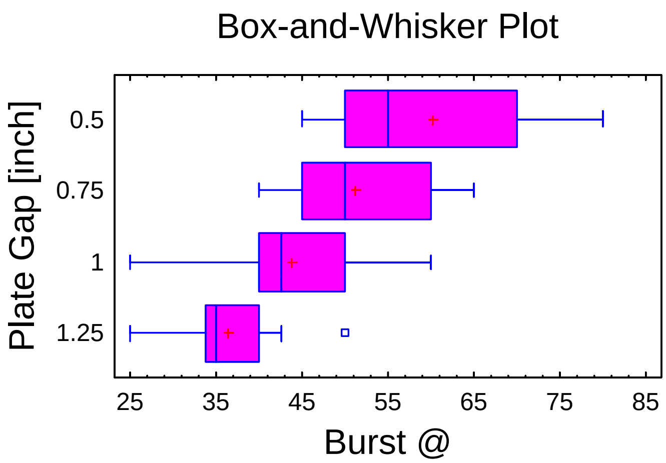
Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

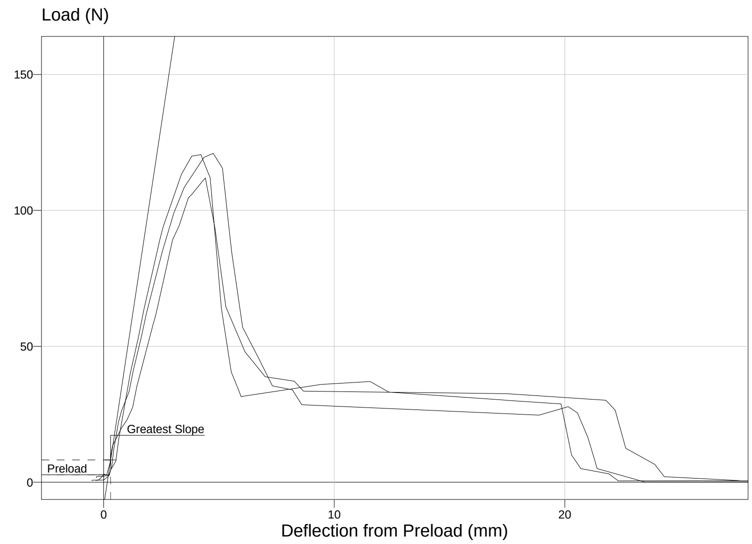
Plate Gap [inch]	Count	Average	Median	Standard Deviation
0.5	11	60.2273	55.0	10.8659
0.75	12	51.25	50.0	8.75811
1	12	43.75	42.5	10.6867
1.25	12	36.4583	35.0	6.1661
Total	47	47.6596	45.0	12.5802


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
25
35
45
55
65
75
85
Burst @

5.6. Preformed MRE, 8 oz, sourced by Demo Site and sealed by Demo Site

Pouch Description
Pouch Size: 4-1/4” x 7-1/4” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

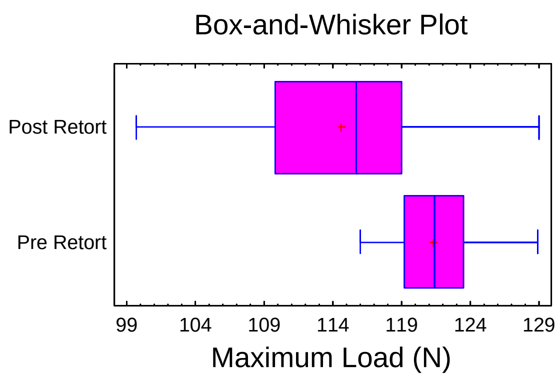
Seal Strength Data
Three seal samples were taken from the Demo Site seal and none from the manufacturers seal. The Demo site seal was the weaker seal and more likely to fail during the burst test



Stress/Strain Curves from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	36	114.649	115.715	7.0187
Pre Retort	18	121.276	121.365	3.23538
Total	54	116.858	118.0	6.77003



Minimum Seal Strength Post Retort/Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch (first row) and lbf/inch (second row)

112	108	100	106	116	103	114	102	104	109	118	116
25.1	24.2	22.4	23.8	26.0	23.1	25.6	22.9	23.3	24.4	26.5	26.0

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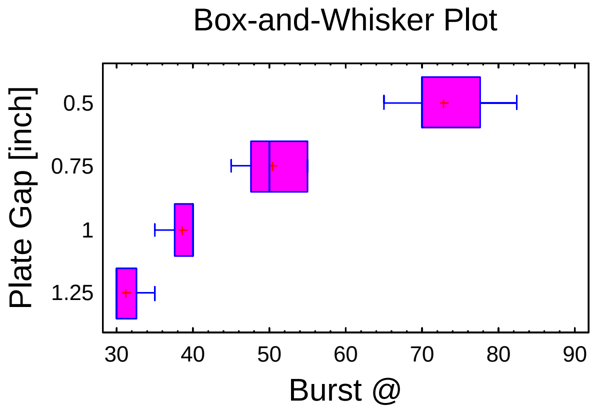
Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

Plate Gap [inch]	Count	Average	Median	Standard Deviation
0.5	12	72.7083	70.0	5.78579
0.75	12	50.4167	50.0	3.96481
1	12	38.5417	40.0	1.9824
1.25	12	31.25	30.0	1.99431
Total	48	48.2292	42.5	16.2834

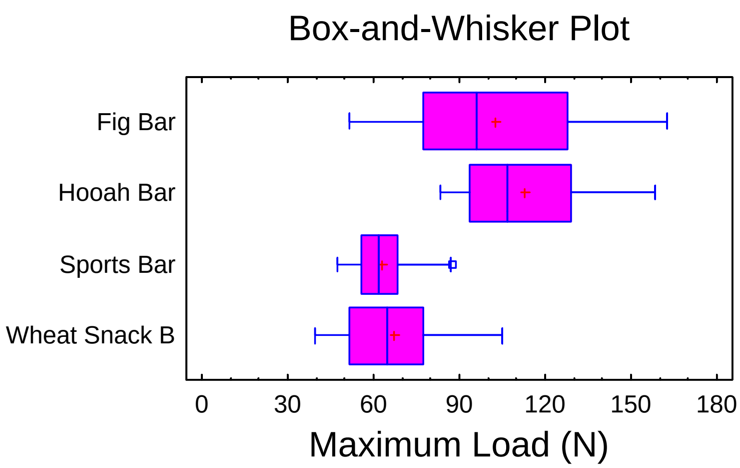

Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
30
40
50
60
70
80
90
Burst @

5.7. HFFS Bakery Pouch, sourced from Sterling

Seal Strength Data

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Fig Bar	40	102.337	96.285	31.8891
Hooah Bar	40	112.565	106.72	21.2983
Sports Bar	38	63.2163	61.5	10.357
Wheat Snack B	39	67.031	64.5	16.7101
Total	157	86.7038	80.0	30.4365



5.8. HFFS Hoaah Bar Pouch, sourced from Sterling

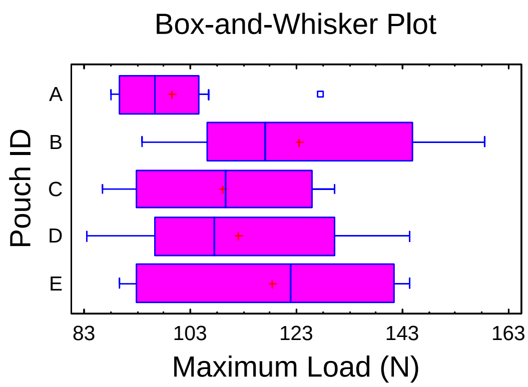
Pouch Description
Pouch Size: 3” x 6-1/4” (inside seal)
Pouch Specification: Compliant with PCR-H-008

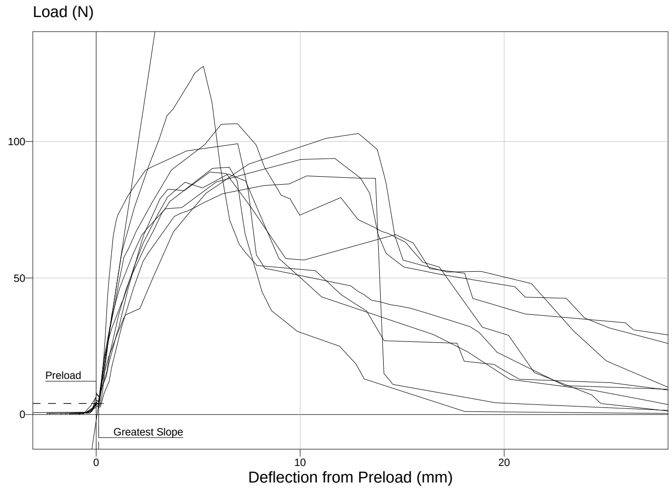
Seal Strength Data:

Seal Samples taken from all four sides of the pouch, A total of 5 pouches were tested

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
A	8	99.64	96.44	13.1208
B	8	123.618	117.19	23.6976
C	8	109.16	109.685	18.1139
D	8	112.074	107.665	21.4462
E	8	118.335	122.05	24.9681
Total	40	112.565	106.72	21.2983





Stress/Strain Curves of one pouch

Minimum Seal Strength Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch (first row) and lbf/inch (second row)

88	94	86	84	90
19.8	21.1	19.3	18.9	20.2

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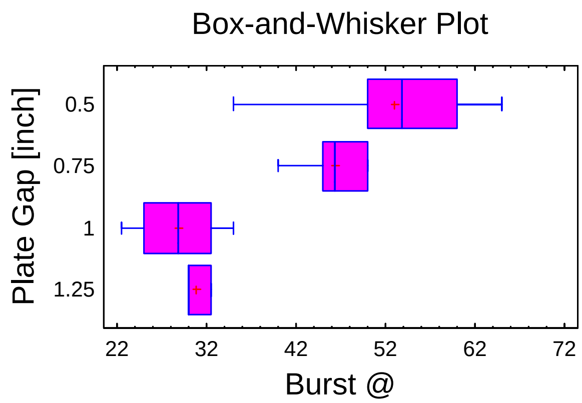
Burst Strength Data

```
Summary Statistics of the pressure at which the pouch burst [psig]
                                                          Standard
Plate Gap [inch]     Count          Average      Median       Deviation
-------------------------------------------------------------------------
0.5                  6              52.9167      53.75        10.5376
0.75                 6              46.25        46.25        3.79144
1                    6              28.75        28.75        5.18411
1.25                 6              30.8333      30.0         1.29099
-------------------------------------------------------------------------
Total                24             39.6875      35.0         11.9171
```


Box-and-Whisker Plot
0.5
0.75
1
1.25
Plate Gap [inch]
22
32
42
52
62
72
Burst @

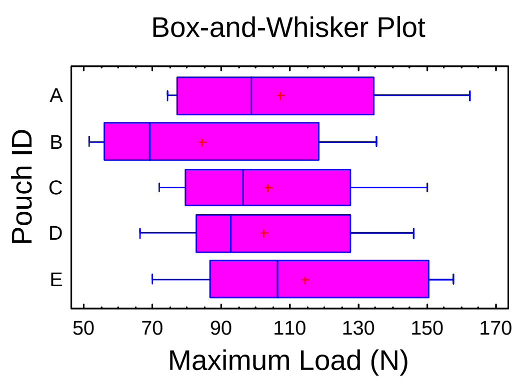
5.9. HFFS Fig Bar Pouch, sourced from Sterling

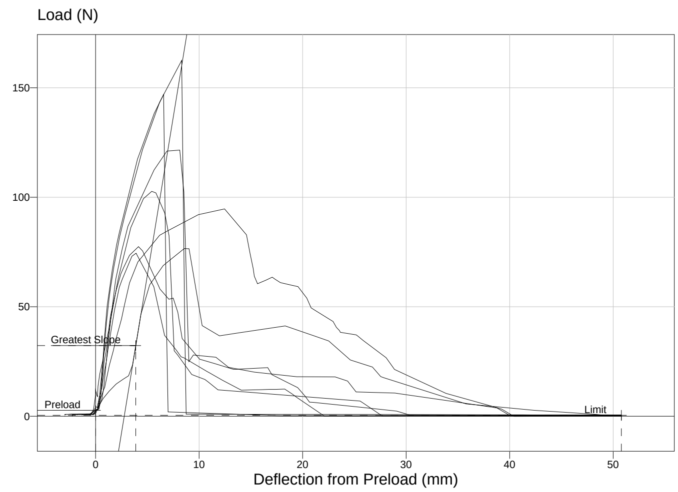
Pouch Description
Pouch Size: 3-3/4” x 5-1/8” (inside seal)
Pouch Specification: Commercial Item Description AA-20295C, Packaging Requirements specified in Assembly Document (ex:ACR-M-027)

Seal Strength Data;
Samples were taken from all sides. A total of five pouches were tested

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
A	8	107.14	98.695	33.6257
B	8	84.2788	69.285	34.2747
C	8	103.611	96.25	28.3095
D	8	102.3	92.64	28.7372
E	8	114.352	106.525	34.1623
Total	40	102.337	96.285	31.8891





Stress Strain Curves from one pouch

Minimum Seal Strength Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch (first row) and lbf/inch (second row)

75	52	72	67	70
16.8	11.7	16.2	15.0	15.7

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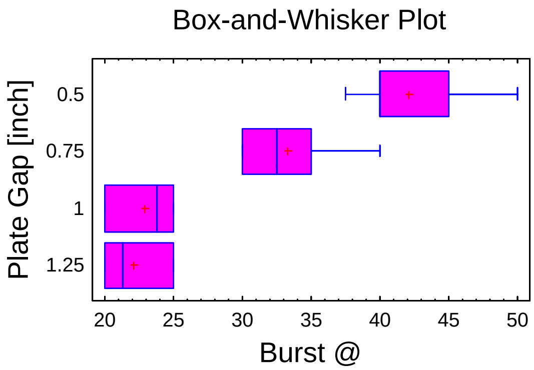
Burst Strength Data

```
Summary Statistics of the pressure at which the pouch burst [psig]
                                                       Standard
Plate Gap [inch]   Count         Average       Median        Deviation
------------------------------------------------------------------------
0.5                6             42.0833       40.0          4.58712
0.75               6             33.3333       32.5          4.08248
1                  6             22.9167       23.75         2.45798
1.25               6             22.0833       21.25         2.45798
------------------------------------------------------------------------
Total              24            30.1042       27.5          9.01325
```



Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
20
25
30
35
40
45
50
Burst @

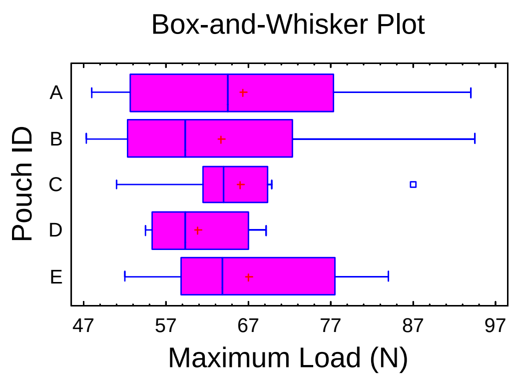
5.10. HFFS Chocolate Sports Bar Pouch, , sourced from Sterling

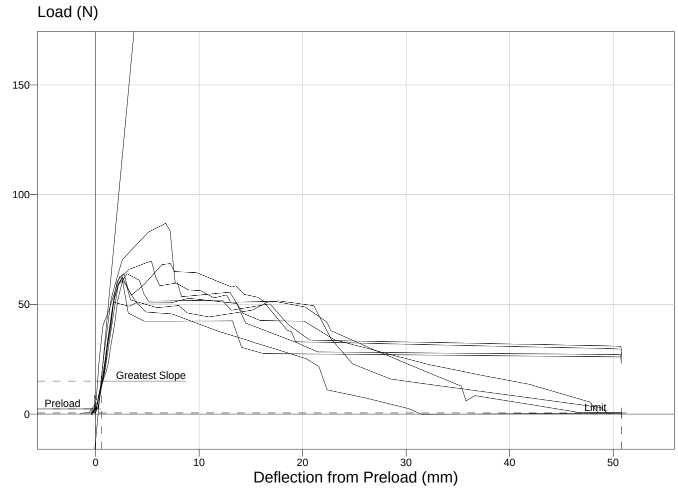
Pouch Description
Pouch Size: 3-3/4” x 5-1/8” (inside seal)
Pouch Specification: Compliant with PCR-C-0004

Seal Strength Data:
Samples were taken from all four sides of the pouch. A total of five pouches were tested.

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
A	8	66.3762	64.5	16.6668
B	8	63.7188	59.325	15.5722
C	8	65.9338	64.0	10.2455
D	8	60.8237	59.25	6.05336
E	8	66.9875	63.75	11.7196
Total	40	64.768	63.0	12.1938





Stress/Strain Curves from one pouch

Minimum Seal Strength Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch (first row) and lbf/inch (second row)

48	47	51	54	52
10.8	10.6	11.4	12.1	11.7

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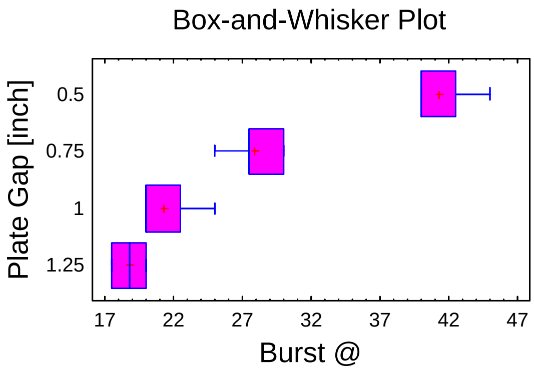
Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

Plate Distance	Count	Average	Median	Standard Deviation
0.5	6	41.25	40.0	2.09165
0.75	6	27.9167	27.5	1.88193
1	6	21.25	20.0	2.09165
1.25	6	18.75	18.75	1.36931
Total	24	27.2917	25.0	9.08644


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
17
22
27
32
37
42
47
Burst @

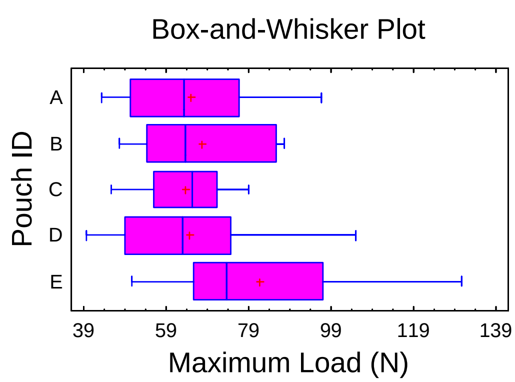
5.11. HFFS Snack Bread Pouch, sourced from Sterling

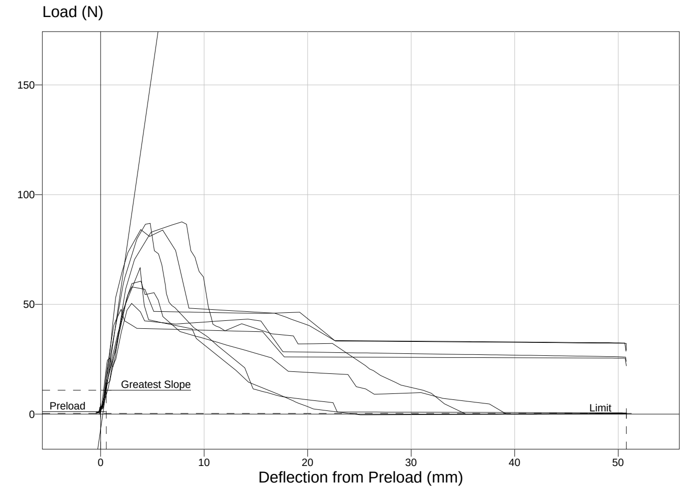
Pouch Description
Pouch Size: 5-1/8" x 5-1/8" (inside seal)
Pouch Specification: Compliant with PCR-S-009

Seal Strength Data:
Samples were taken from all four sides of the pouch. A total of five pouches were tested.

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
A	8	65.0687	63.34	18.7551
B	8	67.7887	63.68	16.4037
C	8	63.7537	65.25	10.9909
D	8	64.7513	62.925	20.6432
E	8	81.7263	73.77	25.5624
Total	40	68.6178	65.25	19.3074





Stress/Strain Curves from one pouch

Minimum Seal Strength Pouch

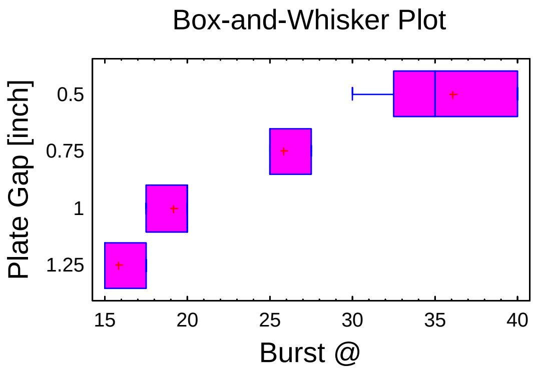
The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch (first row) and lbf/inch (second row)

43	48	46	40	51
9.7	10.8	10.3	9.0	11.4

Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

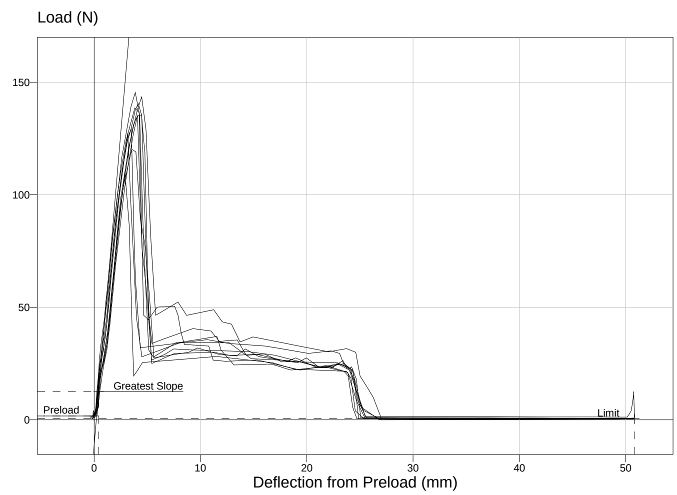
Plate Distance	Count	Average	Median	Standard Deviation
0.5	7	36.0714	35.0	4.04587
0.75	6	25.8333	25.0	1.29099
1	6	19.1667	20.0	1.29099
1.25	6	15.8333	15.0	1.29099
Total	25	24.7	25.0	8.39519


Box-and-Whisker Plot
Plate Gap [inch]
0.5
0.75
1
1.25
15
20
25
30
35
40
Burst @

5.12. Institutional Pouch, sourced from Demo Site, sealed by Demo Site

Pouch Description
Pouch Size: 11” x 14.5” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

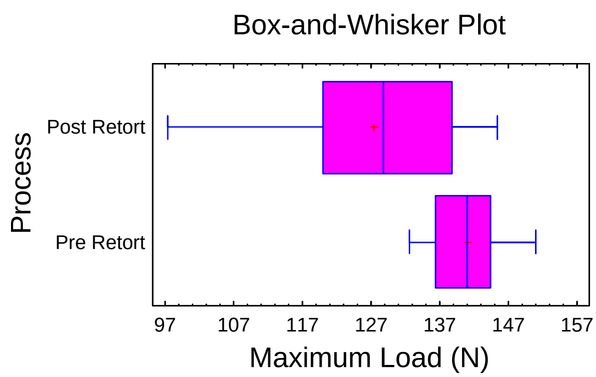
Seal Strength Data
Seal Strength Data based on the manufactured seal of the pouch as the manufactured seal failed during the burst test



Stress/Strain Curves from the manufactured seal

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	40	127.313	128.75	13.2493
Pre Retort	9	141.009	141.0	6.05749
Total	49	129.828	133.0	13.3213



Minimum Seal Strength Post Retort/Pouch
The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

104	110	106	98
23.3	24.7	23.8	22.0

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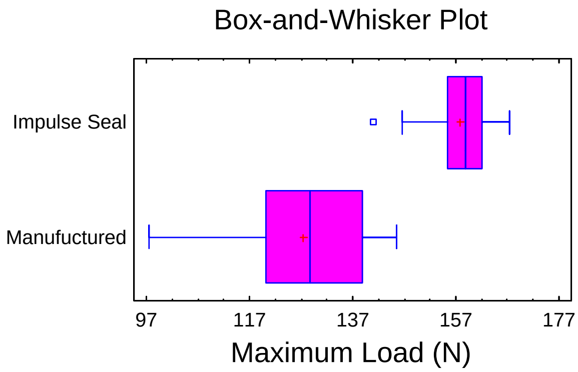
The following Data set is from Post Retorted Pouches and compares the seal strength of the pre-manufactured seal to the impulse seal applied by the Demo Site. As can be seen the impulse seal is significant stronger than the pre-manufactured seal, explaining why the pouch would fail in the pre manufactured seal rather than in the impulse seal

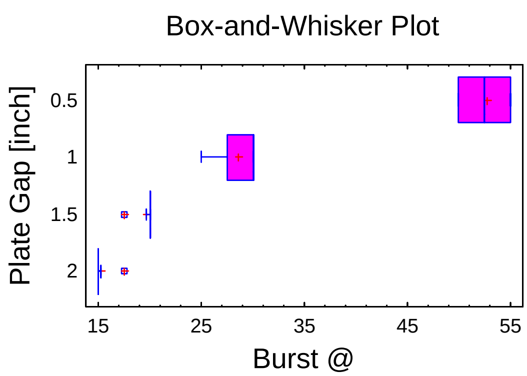
Code	Count	Average	Median	Standard Deviation
Impulse Seal	40	157.894	158.85	6.06475
Manufactured	40	127.313	128.75	13.2493
Total	80	142.603	145.0	18.4818



Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

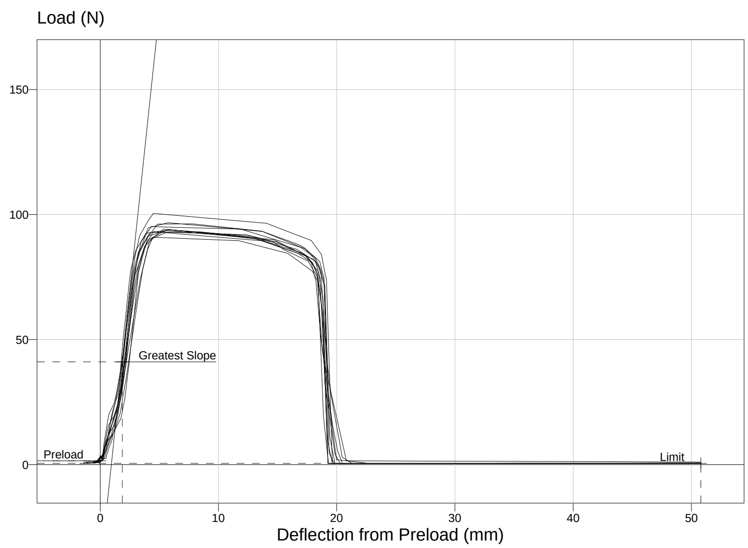
Plate Distance	Count	Average	Median	Standard Deviation
0.5	9	52.7778	52.5	2.3199
1	9	28.6111	30.0	2.20479
1.5	9	19.7222	20.0	0.833333
2	9	15.2778	15.0	0.833333
Total	36	29.0972	22.5	14.786



5.13. Institutional Pouch, sourced from Natick, sealed by Demo Site

Pouch Description
Pouch Size: 10.25 * 15.75” (inside seal)
Pouch Specification: Compliant with MIL-PRF-44073F, Retorted Pouch

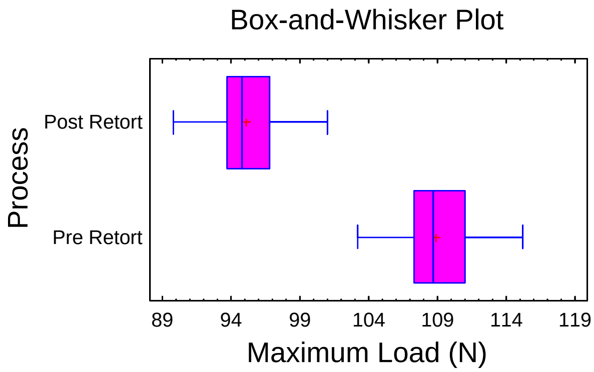
Seal Strength Data
Seal Strength Data is based on the pre-manufactured seal on the long side of the pouch as this side of the seal did fail consistently during the burst test



Stress/Strain Curves from one pouch

Summary Statistics: Maximum Load [N/inch]

Code	Count	Average	Median	Standard Deviation
Post Retort	89	95.1362	94.83	2.40075
Pre Retort	48	108.887	108.745	2.98112
Total	137	99.9539	96.95	7.08194



Minimum Seal Strength Post Retort/Pouch

The lowest value of the maximum load of each test sample was determined for each pouch tested and considered to be the weakest area of the seal and the area in which the pouch will fail during a burst test. The table contains the lowest value for each pouch both in units of N/inch and lbf/inch

94	91	94	90
21.1	20.4	21.1	20.2

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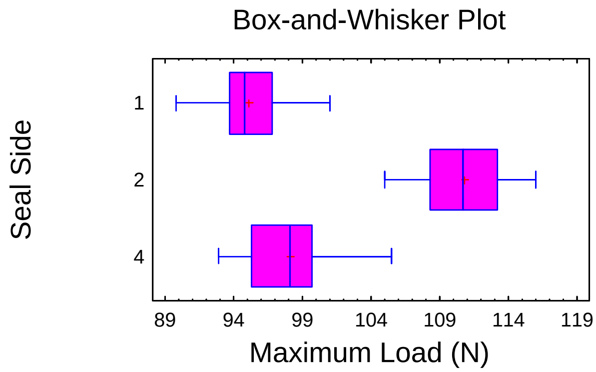
In the table below a comparison is made between the seal strength of the four different pouch seals. The data of the long seal side was combined. Comparing the seal strength of the pre manufactured long seal (1), short seal (3) and Demo Site seal (4), we can see that the long seal is slightly weaker than the Demo Site Seal(4) and significant weaker than the pre manufactured seal on the short side, explaining why the pouch always failed on the long side during the burst test

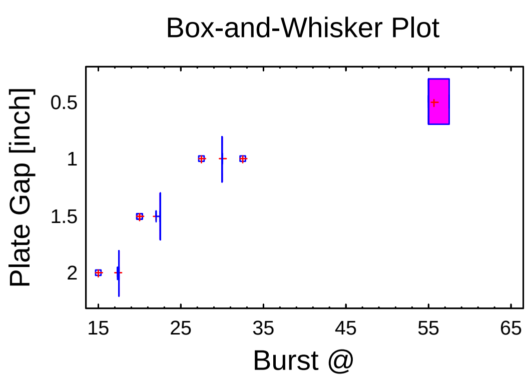
Code	Count	Average	Median	Standard Deviation
Long Side	89	95.1362	94.83	2.40075
Short Side	35	110.806	110.66	3.14362
Rutgers Seal	36	98.1097	98.09	3.16205
Total	160	99.2329	96.805	6.83121



Burst Strength Data

Summary Statistics of the pressure at which the pouch burst [psig]

Code	Count	Average	Median	Standard Deviation
0.5	10	55.75	55.0	1.20761
1	10	30.0	30.0	1.17851
1.5	10	22.0	22.5	1.05409
2	10	17.25	17.5	0.790569
Total	40	31.25	25.0	15.0852



COMBAT RATION NETWORK

FOR

TECHNOLOGY IMPLEMENTATION

Internal Pressure Protocol

Institutional Sized Pouches

Technical Working Paper (TWP) #224

Henderikus Bruins

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1. Introduction

Minimum seal strength of a pouch can be determined by inflating a pouch while it is constraint between two plates.

Current specifications for pouches (MIL-PRF-44073F) require that the seals of pouches are tested via an internal pressure test to validate that the seals resist a minimum internal pressure of 20 psig for 30 sec, while the pouch is constraint between two plates. Two test methods are allowed, the most common one being the three sided seal tester and as an alternate a four sided seal tester.

However, the test protocol for Institutional Sized Pouches (ISP) requires that the plates distance is set at 2" and the pouches need to be pressurized at 20 psig. Industry members that have tested ISP at these conditions have remarked that pouches consistently fail at these conditions.

Short Term Project STP#2025, developed a relationship between internal pressure, the plate distance and seal strength and let to the modification in the packaging specification that now allows the use of the internal pressure test with an alternate 1" plate gap and a reduced pressure requirement (12 psig for 30 seconds).

The project showed that the current qualified ISP pouches fail once they are pressurized at either 15 psig or 17.5 psig for 30 second.

In the second part of this project, we have looked at the minimum seal strength requirements for the ISP to assure that it will survive the standard vibration and drop test protocols. Because of the higher mass in the pouch (~6 lbs), the forces on the seal during these tests are significant higher than in an 8 oz MRE pouch.

2. Objective:

Use two sealing conditions to seal Institutional Pouches filled with water. Sealing conditions should make strong tacky seals and weak fusion seals. Retort pouches to reflect production conditions and any changes that this might have on the seal strength characteristics. Expose these pouches to the required vibration test and 10 point drop test as specified in MIL-PRF-44073. Evaluate the pouches for seal creep or open seals. Those pouches that passed the vibration and drop tests will then be tested for burst strength, using the four sided seal tester with a 2 inch gap. The minimum burst strength data will be used to recommend the conditions to be used for an internal pressure protocol.

3. Method:

3.1. Pouches

Pouches from Natick's inventory wee used for this test. The pouches were sources from Japan.

3.2. Filling

A total of 80 Institutional Pouches were filled with 6 lbs of water.

3.3. Sealing

A Multivac impulse vacuum sealer, model 4808, was used to seal the pouches under a vacuum setting of 26" Hg, at two different heat settings: "4.5" and "4.75". This setting is directly related to the time that current is sent through the heating ribbon. The higher number will result in a stronger seal. As heat might built up in the impulse sealer head, three initial cycles were used to preheat the sealing head and the cycle time from seal to seal was then controlled at 50 seconds.

3.4. Retorting

All pouches were retorted in a full water immersion retort at 250 F for 60 minutes.

3.5. Packaging

All pouches were double folded at the pre-sealed side and inserted in a cardboard sleeve with end flaps. Pouches with the weakest seals were packed in a 2 gal zip lock bag to prevent water spillage during the vibration and drop test, as this could weaken the cardboard structure. Four sleeved pouches were then packed in a lined fiberboard box, conforming to style RSC-L, type CF, grade 275 of ASTM D 5118, with the final manufacturing seal pointing towards the case joint. The box was closed in accordance with ASTM D 1974.

3.6. Vibration Test

Four cases were placed on a vibration table for 60 minutes while exposed a vibration test in accordance with ASTM D 999 with a frequency of 268 Hz.

3.7. Drop Test

A drop test in accordance with ASTM D 5276. Ten Drop Cycle from a height of 21 inches was performed. The drop included: (1) a bottom corner drop at the manufacturer's joint; (2 & 3) edge drops on the shortest and next shortest edges radiating from the corner; (4) an edge drop on the longest edge radiating from that corner; (5 & 6) flat-wise drops on the smallest and opposite smallest faces; (7 & 8) flat-wise drops on the medium and opposite medium faces; (9 & 10) flat-wise drops on the longest and opposite longest faces.

3.8. Inspection

After completion of the drop test, each pouch was removed from the box and examine visually for cracked, split or leaking ISP at any location, or tear, hole, or puncture through the carton causing a hole in the ISP; or wet or stained carton due to one or more leaking ISPs; or any evidence of food product leakage from the pouch.

3.9. Burst Test

Pouches that passed the visual exam after the vibration and drop test were then exposed to a burst test. The burst test was performed while confining the pouch between two plates with a 2" gap. The initial inflation pressure was initially set at 2.5 psig for 30 seconds. If the seal passed (no burst), the pressure was increased in 2.5 psig steps to 5, 7.5, 10, 12.5, … psig. and held for 30 seconds at each setting until burst occurs. After the pouch seal failed, the failed seal was inspected and quantified as non-fusion, weak fusion, or fusion based on the color of the pulled apart seal interface.

4. Results

The Raw Test Date can be found in the Appendix. The table below summarizes this data.

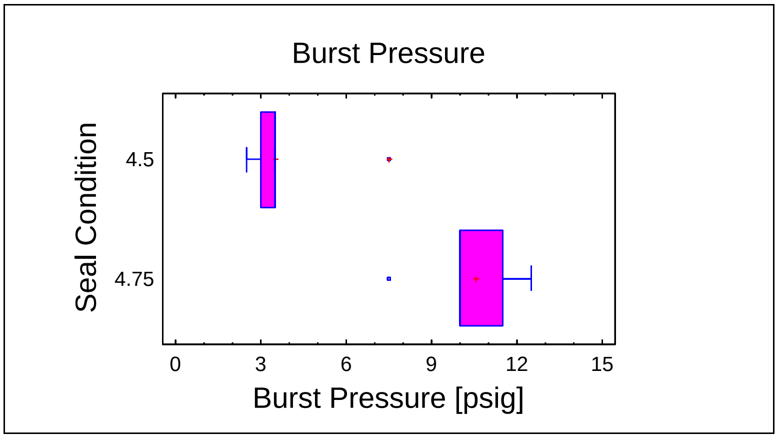
4.1. Visual Inspection after Vibration and Drop Testing

	Seal "4.5"	Seal "4.75"	Total
Fail 24		4	28
Pass 16		34	50
Total 40		38 Note: two pouches rejected due to pinholes in fold over	78

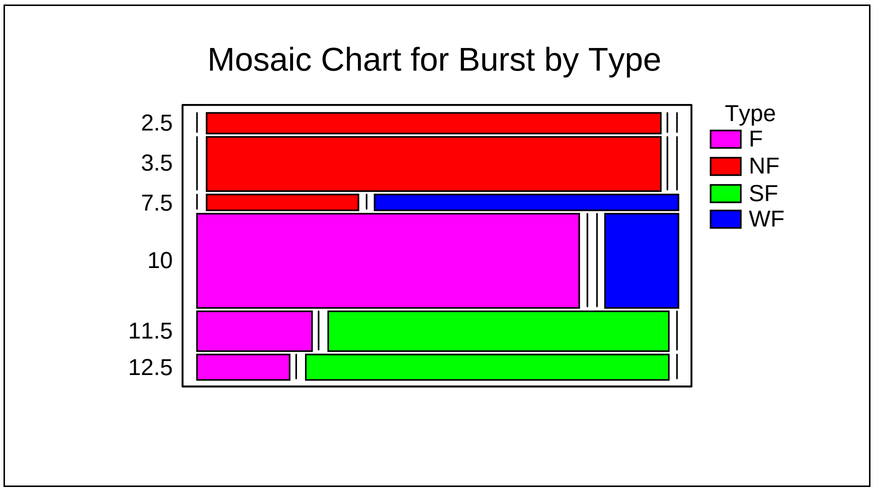
1. Of the 80 pouches that were filled, 40 pouches were sealed at the setting “4.5” and 40 pouches were sealed at the setting “4.75”
2. Of the 40 pouches sealed at “4.5”, 24 failed and 16 passed
3. Of the 40 pouches sealed at “4.75”, 2 failed due to pinholes in the body of the pouch, 4 failed due to open seals and 34 passed

4.2. Bust Testing

Of the 16 pouches sealed at “4.5” that passed the vibration and drop test, only one pouch had a weak fusion seal and failed at a pressure setting of 7.5 psig. The other 15 pouches had tacky seals (no fusion) and failed at either 2.5 or 5 psig



Of the 34 pouches sealed at “4.75” that passed the vibration and drop test, two pouches failed at 7.5 psig (one of them was quantified as a non fusion seal), 19 failed at 10 psig, and 13 failed at 12.5 psig.



*: Type: NF = Non Fusion; WF = Weak Fusion; F = Fusion; SF = Strong Fusion

All the pouches that passed the 7.5 psig pressure test but failed at 10 psig (19 pouches), three of the pouches were quantified as weak fusion seal

All pouches that passed the 10 psig pressure test but failed at 12.5 psig (13 pouches) showed a fusion or strong fusion seal.

5. Conclusion

Because a strong tacky seal (NF) can withstand a 5 psig internal pressure test, the conditions need to be set higher than 5 psig to sort out these defective pouches

A weak looking fusion seal (WF) can withstand the drop and vibration test and a 7.5 psig internal pressure test. They are likely to survive the distribution system at ambient conditions.

Pouches that withstand a 10 psig internal pressure test have good fusion seals (F & SF).

While a 7.5 psig internal pressure test might be adequate to assure that pouches stay intact during the life cycle of the pouch, we recommend that the internal pressure test requirements are set at 10 psig for 30 seconds. This gives us a safety margin and still stay below the burst pressure of optimal sealed ISP (15 psig)

6. Recommendation

It is recommended that the MIL-PRF-44073 document is modified to reflect a 10 psig internal pressure condition for the ISP.

4.5.6 <u>Internal pressure test</u>. Internal pressure resistance shall be determined by pressurizing the pouches while they are restrained between two rigid plates. The plates shall be 1/2 inch ± 1/16 inch apart or 1 inch ± 1/16 inch apart for SSP, or 2 inches ± 1/16 inch apart for ISP. If a three-seal tester (one that pressurizes the pouch through an open end) is used, the closure seal shall be cut off for testing the side and bottom seals of the pouch; for testing of the closure seal, the bottom seal shall be cut off. The pouches shall be emptied prior to testing. If a four-seal tester (designed to pressurize filled pouches by use of a hypodermic needle through the pouch wall) is used, all four seals can be tested simultaneously. For SSP, the pressure shall be 20 psig for the 1/2 inch plate distance and 12 psig for the 1 inch plate distance. ***For ISP, the pressure shall be 10 psig for the 2 inch plate distance.*** *Pressure shall be applied gradually until pressure set point is reached. The pressure set point shall be held constant for 30 seconds and then released.*

The pouches shall then be examined for separation or yield of the seals. Any rupture of the pouch or evidence of seal separation greater than 1/16 inch in the pouch manufacturer's seal shall be considered a test failure. Any seal separation that reduces the effective closure seal width to less than 1/16 inch (see table II) shall be considered a test failure and shall be cause for rejection of the lot.

7. Appendix

Case	Layer	Seal	Pass/Fail	Comment	IP Pass [psig]	Burst [psig]	Type *
A	1	4.75	1	Pass	7.5	10	F
A	2	4.75	1	Pass	7.5	10	F
A	3	4.75	1	Pass	10	12.5	SF
A	4	4.75	1	Pass	7.5	10	F
B	1	4.75	1	Pass	10	12.5	SF
B	2	4.75	1	Pass	7.5	10	F
B	3	4.75	1	Pass	10	12.5	F
B	4	4.75	1	Pass	7.5	10	F
C	1	4.75	1	Pass	7.5	10	F
C	2	4.75	1	Pass	7.5	10	F
C	3	4.75	1	Pass	10	12.5	SF
C	4	4.75	1	Pass	10	11.5	F
D	1	4.75	3	Pin Hole Leak			
D	2	4.75	1	Pass	10	11.5	SF
D	3	4.75	1	Pass	10	11.5	SF
D	4	4.75	1	Pass	10	11.5	SF
E	1	4.75	1	Pass	10	11.5	F
E	2	4.75	1	Pass	10	11.5	SF
E	3	4.75	1	Pass	7.5	10	F
E	4	4.75	1	Pass	7.5	10	F
F	1	4.5	1	Pass/Creep	2.5	3.5	NF
F	2	4.5	0	Fail			
F	3	4.5	0	Fail			
F	4	4.5	0	Fail			
G	1	4.5	1	Pass	2.5	3.5	NF
G	2	4.5	1	Pass	0	2.5	NF
G	3	4.5	1	Pass	2.5	3.5	NF
G	4	4.5	0	Fail			
H	1	4.5	1	Pass/Creep	2.5	3.5	NF
H	2	4.5	0	Fail			
H	3	4.5	1	Pass	0	2.5	NF
H	4	4.5	0	Fail			
I	1	4.5	1	Pass	2.5	3.5	NF
I	2	4.5	1	Pass	2.5	3.5	NF
I	3	4.5	0	Fail			
I	4	4.5	1	Pass	2.5	3.5	NF
J	1	4.5	1	Pass	2.5	3.5	NF
J	2	4.5	1	Pass	5	7.5	WF
J	3	4.5	1	Pass	2.5	3.5	NF
J	4	4.5	1	Pass	2.5	3.5	NF
K	1	4.75	1	Pass/Creep	5	7.5	WF
K	2	4.75	1	Pass	7.5	10	WF

K	3	4.75	1	Pass/Creep	7.5	10	F
K	4	4.75	3	Pin Hole Leak			
L	1	4.75	1	Pass	7.5	10	F
L	2	4.75	1	Pass	7.5	10	F
L	3	4.75	1	Pass	10	11.5	SF
L	4	4.75	0	Fail			
M	1	4.75	1	Pass	10	11.5	SF
M	2	4.75	1	Pass	7.5	10	F
M	3	4.75	0	Fail			
M	4	4.75	1	Pass	10	12.5	SF
N	1	4.75	0	Fail			
N	2	4.75	1	Pass	7.5	10	F
N	3	4.75	1	Pass	7.5	10	F
N	4	4.75	0	Fail			
O	1	4.75	1	Pass	7.5	10	WF
O	2	4.75	1	Pass/Creep	5	7.5	NF
O	3	4.75	1	Pass	7.5	10	WF
O	4	4.75	1	Pass	7.5	10	F
P	1	4.5	0	Fail			
P	2	4.5	0	Fail			
P	3	4.5	1	Pass	2.5	3.5	NF
P	4	4.5	1	Pass	0	2.5	NF
Q	1	4.5	0	Fail			
Q	2	4.5	0	Fail			
Q	3	4.5	0	Fail			
Q	4	4.5	0	Fail			
R	1	4.5	0	Fail			
R	2	4.5	0	Fail			
R	3	4.5	1	Pass	0	2.5	NF
R	4	4.5	0	Fail			
S	1	4.5	0	Fail			
S	2	4.5	0	Fail			
S	3	4.5	0	Fail			
S	4	4.5	0	Fail			
T	1	4.5	0	Fail			
T	2	4.5	0	Fail			
T	3	4.5	0	Fail			
T	4	4.5	0	Fail			

*: Type: NF = Non Fusion; WF = Weak Fusion; F = Fusion; SF = Strong Fusion